American Journal of Agricultural Economics

CUl-H03160-28-P08898

Volume 73 • Number 4 • November 1991

Also in this issue: Other articles, comments and replies, and book reviews.

28

AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

AAEA Annual Meeting
Baltimore, Maryland
9–12 August 1992

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to:

Peter J. Barry, Editor
Department of Agricultural Economics
University of Illinois
305 Mumford Hall
1301 W. Gregory Drive
Urbana, Illinois 61801

Effective 1 February 1991, submissions of new manuscripts should be sent to: Steven T. Buccola and Richard M. Adams, Co-editors, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, OR 97331-3601.

Communications concerning book reviews and books submitted for announcement in the ***Journal*** should be sent to the book review editor: Otto Doering, Department of Agricultural Economics, Krannert Building, Purdue University, West Lafayette, IN 47907.

Editorial Policy

The purpose of the ***Journal*** is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged. The ***American Journal of Agricultural Economics*** (ISSN 0002-9092) is published monthly in February, May, August, November, and December by the American Agricultural Economics Association, 80 Heady Hall, Iowa State University, Ames, Iowa and printed by Edwards Brothers, Inc., Ann Arbor, MI. Second-class postage is paid at Ames, Iowa, and additional mailing offices. Postmaster: Send address changes to the American Journal of Agricultural Economics, 80 Heady Hall, Iowa State University, Ames, Iowa, 50011-1070.

Subscription

Subscription cost is $65 per year plus foreign postage; members receive copies as part of their membership fee of $60 per year.

American Journal of Agricultural Economics

Volume 73 • *Number 4* • *November 1991*

Articles

Comments and Replies

Books Reviewed

Call for Papers: 75th Anniversary Issue of *AJAE*

In 1993, the *American Journal of Agricultural Economics* will celebrate its 75th anniversary. To commemorate 75 years of published research in agricultural, natural resource, and rural economics, AAEA will produce a special October 1993 issue of the *Journal*. The special issue will contain approximately ten essays on (*a*) the state and future of applied economics research methodology (philosophy of our science) and (*b*) the condition and likely future of the agricultural economics profession.

Format. Approximately three essays will be solicited from prominent scholars outside our profession; the remainder will be chosen competitively. Winners of the competitive paper slots will be selected by a ten-member committee appointed by the *AJAE* editorial board in consultation with past *AJAE* editors. Essays should be 15–30 double-spaced pages long. Published papers will be subject to the usual *Journal* page charge.

Topic areas. Sample topic areas include the following: Increased use of mathematics in research and reporting—benefits and problems. Does our profession have a complementary product mix? Prospects for multidisciplinary research in the face of increased specialization. Has the dream of rigorous hypothesis testing proven illusive? Extension's niche in increasingly commercial information markets. Future of agricultural economics in a nation of declining farm numbers.

Other sample topics are available from the *Journal* editors; these are suggestions only and are not exclusive. Acceptable topics do not include (*a*) specific research or policy issues (the subject of CHOICES' "Choices for the 21st Century" competition); (*b*) literature reviews or expositions of specific research methods.

Submission\Format. Individuals wishing to compete for an essay slot should submit to the *AJAE* editors a 5–10 double-spaced-page summary paper. The summary should lay out clearly and in substantial detail the proposed theme, manner in which the theme will be developed, and principal conclusions.

Address submissions to Steve Buccola and Rich Adams, *AJAE* editors, Department of Agricultural and Resource Economics, Oregon State University, Ballard Hall 213, Corvallis OR 97331-3601. Questions may be directed to either editor at (503) 737-1410 or (503) 737-1435.

Timetable

1 February 1992.	Paper summaries are due from authors.
1 April 1992.	Winners of competitive paper slots are announced.
1 October 1992.	Preliminary paper drafts are due from authors.
1 February 1993.	Final paper drafts are due from authors.
1 May 1993.	Edited papers are sent to the publisher.

Articles

The Farm–Retail Price Spread in an Imperfectly Competitive Food Industry

Garth J. Holloway

Gardner's popular model of perfect competition in the marketing sector is extended to a conjectural-variations oligopoly with endogenous entry. Revising Gardner's comparative statics on the "farm–retail price ratio," tests of hypotheses about food industry conduct are derived. Using data from a recent article by Wohlgenant, which employs Gardner's framework, tests are made of the validity of his maintained hypothesis—that the food industries are perfectly competitive. No evidence is found of departures from competition in the output markets of the food industries of eight commodity groups: (*a*) beef and veal, (*b*) pork, (*c*) poultry, (*d*) eggs, (*e*) dairy, (*f*) processed fruits and vegetables, (*g*) fresh fruit, and (*h*) fresh vegetables.

Key words: conjectural-variations oligopoly, farm–retail price ratio, food industry conduct.

In a previous article in this *Journal,* Gardner investigated the effects of three distinct forces affecting food system equilibria: shifts in retail demand, shifts in farm commodity supply, and shifts in marketing input supply. He derived comparative-static predictions about how the quotient of retail and farm prices—the "retail–farm price ratio"—would adjust to changes in each of these exogenous effects. The investigation was conducted within a framework that has since been applied to a number of important marketing system issues, including the quantification of downstream research benefits (Alston and Scobie; Freebairn, Davis, and Edwards), the characterization of marketing industry efficiency (Kilmer), and the incorporation of marketing group behavior in modeling the demand for farm output (Wohlgenant). Yet, despite this clear popularity as a paradigm for food market analysis, the model's applicability is limited by a number of restrictive assumptions. Perhaps the most stringent of these assumptions is that of perfect competition in the food industries. Indeed, since Gardner's paper, an extensive literature has developed about the potentially noncompetitive conduct of firms in these industries (e.g., Gisser, Mueller and Marion, Connor et al.).

Given the frequency of use of the Gardner framework, two questions arise for applied economic analysis. The first is how Gardner's model may be extended to allow for noncompetitive behavior in food marketing; the second is how some of Gardner's concepts may be applied to identify empirically departures from perfect competition. This paper investigates these issues by identifying the causes and consequences of noncompetitive conduct in the food industries. The specific objectives are to (*a*) provide a conceptual framework for the analysis of imperfect competition in these industries, (*b*) assess the analytical consequences of noncompetitive behavior, and (*c*) determine the empirical significance of such behavior.

The first objective is achieved through an oligopolistic generalization of the Gardner model, which explicitly allows for the entry of new firms into the food industries. The entry issue, which

Garth J. Holloway is an assistant professor, Department of Agricultural Economics, University of California, Davis. This article was accepted for publication while the author was a postdoctoral fellow in the Department of Economics and Marketing, Lincoln University, New Zealand.

Giannini Foundation Research Paper No. 981. Financial support from the New Zealand Meat Producers Board, Purdue University, and Lincoln University is gratefully acknowledged.

Without implication, the author thanks Tom Hertel, who provided insights through numerous conversations about the topic of this paper; Mike Wohlgenant, who kindly made available the data used in the empirical section of the paper; and Gary Brester, who furnished these data. Helpful comments on earlier drafts were received from Jim Binkley, Paul Preckel, Richard Sexton, John Weinberg, several *Journal* reviewers, and seminar participants at the University of California, Davis.

is accounted for only implicitly in the Gardner framework, is shown to be an important, though hitherto neglected, determinant of food-system equilibrium. To achieve the second objective, the comparative-static properties of the noncompetitive equilibria are established and are compared to those obtained under perfect competition. This procedure addresses the important issue of the economic significance of Gardner's retail–farm price ratio.[1] Specifically, the comparative-static results show how observations on the movement in the ratio can be used to make inferences about conduct in the food industries and, in particular, can be used to test the null hypothesis of perfect competition.

The final objective is achieved by applying this test to the marketing systems for eight food commodities: (*a*) beef and veal, (*b*) pork, (*c*) poultry, (*d*) eggs, (*e*) dairy, (*f*) processed fruits and vegetables, (*g*) fresh fruit, and (*h*) fresh vegetables. These are the commodity groups that were recently analyzed by Wohlgenant. Reworking Wohlgenant's data, tests are made of the validity of his maintained hypothesis, that the food industries are perfectly competitive.

Conjectural Variations, Entry, and the Structure-Conduct-Performance Paradigm

To generalize behavior in the food industries, a convenient mode of conduct to consider is that of conjectural variations (Kamien and Schwartz). Specifically, it is assumed that, when making their output decisions, firms form beliefs about the extent to which these decisions affect the quantity decisions of other firms in the industry and, therefore, the industry price, which is common to all firms. Recent empirical work provides evidence of this behavior in the coffee-roasting industry (Gollop and Roberts), in the cigarette industry (Sumner, Sullivan), in the Canadian food-processing industry (Lopez), and in the beef-packing industry (Schroeter).

To formalize the notion of conjectural variations in the context of the food industries, extend Gardner's notation to consider a number, n, of incumbent firms which face a demand schedule:

$$x = D(P_x; N), \tag{1}$$

where x denotes the quantity of a food product with price P_x and N is an exogenous variable that shifts demand. Given the composition of aggregate output,

$$x = \sum_i x_i, \tag{2}$$

each firm, $i \in \{1, 2, \ldots, n\}$, forms its conjecture, $x = K_i(x_i)$, about the relationship between this aggregate and its own output level. Let $\theta_i \equiv \partial K_i(\cdot)/\partial x_i)(x_i/x)$ denote the elasticity of industry output conjectured by firm i (Appelbaum) and let $\eta \equiv (\partial D(\cdot)/\partial P_x)(P_x/x)$ denote the elasticity of demand for the retail product. Using these expressions in the firm's first-order condition yields

$$P_x(1 + \theta_i/\eta) = C(\cdot), \tag{3}$$

where the firm's marginal cost, $C(\cdot)$ is defined over the price vector (P_a, P_b) and corresponds to a linearly homogenous technology in two variable inputs (a_i, b_i), which denote, respectively, the firm's quantities of a farm commodity and a marketing service input.

In equation (3) two polar cases are easily identified: perfect competition, in which $\theta_i = 0$; and monopoly, or cartel behavior, in which $\theta_i = 1$. Further, by examining the definition of θ_i more closely, an intermediate value of $\theta_i = x_i/x$ is obtained as the result of Cournot behavior. Thus, $\theta_i \in [0,1]$ provides a convenient index of competition within which a broad spectrum of behaviors can be encompassed.[2]

In the remainder of the paper, attention is restricted to symmetric equilibria in which each incumbent firm produces the same level of output. The symmetric equilibrium follows from the assumptions that firms possess identical technologies and produce a homogenous product. Using these assumptions in equation (3) and noting that $C(\cdot)$, P_x, and η are common to all firms, one has: $\theta_i = \theta_j \equiv \theta$, $\forall\, i, j \in \{1, 2, \ldots, n\}$. From the definition of the conjectural elasticities,

$$\theta_i \equiv (\partial K_i(\cdot)/\partial x_i)(x_i/x),\ i \in \{1, 2, \ldots, n\},$$

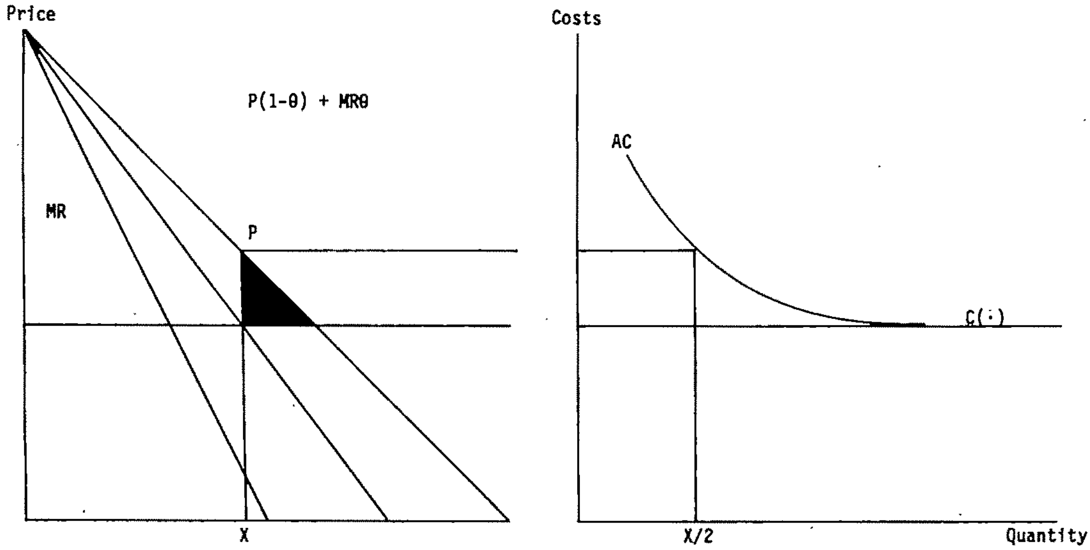
it necessarily follows that

$$(\partial K_i(\cdot)/\partial x_i)x_i = (\partial K_j(\cdot)/\partial x_j)x_j,\ \forall\, i, j \in \{1, 2, \ldots, n\}.$$

To make the popularly invoked Cournot conjecture feasible among all conjectures satisfying this condition, one must have

[1] Both Fisher and an anonymous reviewer have questioned the significance of this ratio.

[2] An alternative to the formal, conjectural-variations interpretation is to consider $\theta_i \in [0,1]$ as the outcome of some unknown game.



(a) Average and marginal revenues

(b) Average and marginal costs

Figure 1. Oligopoly equilibrium

$$x_i = x_j \equiv x_n = x/n, \forall\, i, j \in \{1, 2, \ldots, n\}.$$

The latter aggregation condition has two advantages. First, it is convenient for comparative-static experiments in which the number of firms, n, is endogenous. Second, it facilitates derivation of a relationship between food market structure, food industry conduct, and food market performance. To derive this relationship explicitly, allow for the possibility of nonzero fixed costs, κ, ignore the integer problem,[3] and assume that firms enter the industry until profits are exactly zero:

$$(4) \qquad P_x x_n - C(\cdot)x_n - \kappa = 0.$$

Combining equations (3) and (4) yields: $\theta = -\eta\omega_\kappa$, where $\omega_\kappa \equiv \kappa/P_x x_n$ denotes the share of fixed costs in food industry revenues. This relationship between the conduct variable, θ, and the market structure variables, η and ω_κ, is an intuitively appealing one that indicates the conditions under which θ takes on its limiting values, zero and one. In particular, the perfectly competitive case, $\theta = 0$, is achieved when either demand is perfectly inelastic or the "entry fee," κ, is zero. As the share of fixed costs increases, equations (3) and (4) describe a sequence of equilibria that approaches the monopolistic one. This sequence can be considered with reference to figure 1, which depicts a specific example of the equilibrium circumscribed by equations (3) and (4).

In figure 1a, the left-hand side of the first-order condition, (3), has been rewritten to show that θ can be interpreted as the "weight" in a convex combination of the average and marginal revenues facing the industry (Quirmbach).[4] This makes explicit the fact that, unlike the competitive case in which firms' allocative decisions depend exclusively on average revenues, decisions by oligopolists depend on both the average and marginal revenues facing the industry. For the specific example, it is assumed that average and marginal revenues are equally weighted with $\theta = 1/2$ and that two firms support the equilibrium with output levels $x/2$. Such a situation is consistent with the model's assumptions only if these firms break even, which is suggested explicitly in figure 1b.[5]

Net of fixed costs, the shaded region in figure 1a represents the deadweight loss resulting from

[3]Strictly speaking, n can take only integer values. This value is determined by an entry process that ensures that the nth firm makes nonnegative profits, but that the $n + 1$th firm would make a loss if it decided to enter. With ample precedent, n is assumed to be a continuous variable. This allows equation (4) to be written as a strict equality rather than a weak inequality and therefore avoid the complexities inherent in the latter approach. Any imprecision induced by this assumption is reduced as firm numbers increase.

[4]This interpretation of θ is similar to that used by Just and Chern, who consider imperfect competition in the farm commodity market.

[5]The symmetric equilibrium depicted in figure 1 is in fact the Cournot duopoly in which $\theta = x_n/x = 1/n = 1/2$. It is important to note, however, that costs and demand may be such that the equilibrium with $\theta = 1/2$ may be supported by alternative numbers of firms who have modes of conduct other than Cournot.

noncompetitive conduct. As the value θ increases, so does this shaded area. Hence, this component of market performance is closely related to the value of the conjectural elasticity. In fact, it follows from equation (3) that inferences about market performance can be made by taking a monotonic transformation of θ. Two such transformations which are commonly used are the Harberger measure $I_M = -P_x x\eta\theta^2/2$, which approximates the deadweight loss, and the Lerner index, $I_L = -\theta/\eta$, which measures the distortion in price that is attributable to market power.[6]

Given the relationship $\theta = -\eta\omega_K$, it follows that inferences about conduct and performance can be made solely from observations on the demand elasticity and the fixed-costs share. For many food industries, estimates of η are generally available; estimates of ω_K, however, are generally unavailable or, when available, are often unreliable. Thus, in order to make inferences about conduct and performance in the food industries, an alternative procedure for identifying θ must be pursued. One alternative is to investigate the comparative-static properties of the model under alternative modes of conduct and establish potentially refutable propositions that follow from particular values of θ. In view of its frequent invocation in applied work, the most interesting hypothesis to test is that of perfect competition; hence, the remainder of the paper is devoted to a test of H_0: $\theta = 0$.

Marketing-System Equilibrium

Equilibrium in the food-marketing system is completely described by equations (1)–(4) and the six equations that follow. These equations represent, respectively, input demands for the two factors of production:

$$(5) \qquad a_n = \partial C(\cdot)x_n/\partial P_a,$$

$$(6) \qquad b_n = \partial C(\cdot)x_n/\partial P_b;$$

aggregation conditions in the symmetric equilibrium:

$$(7) \qquad a = na_n,$$

$$(8) \qquad b = nb_n;$$

[6]Another commonly used performance index can be derived in the specific case of Cournot behavior. This is the Herfindahl index: $I_H = n\theta^2$.

and inverse-supply relations for the farm commodity and the marketing input, respectively:

$$(9) \qquad P_a = h(a; W),$$

$$(10) \qquad P_b = g(b; T).$$

Equations (9) and (10) follow Gardner's specification of the exogenous variables W and T. Although rather general interpretations of these shift variables are permissible during comparative statics, the precise specifications of W and T will play an important role in the identification of the perfectly competitive equilibrium. Accordingly, more specific interpretations are given below.

Allowing the system in (1)–(10) to be displaced by movements in the exogenous variables, one may solve for the equilibrating adjustments in each of the endogenous variables: P_x, x, x_n, P_a, a, a_n, P_b, b, b_n, and n. To derive these effects note the definition of the conjectural-variations elasticity in the symmetric equilibrium, $\theta \equiv (\partial K_n(\cdot)/\partial x_n)(x_n/x)$, and use the properties of the dual unit cost function (Allen, p. 504) to express the displaced system in percent-change terms, as follows:

$$(11) \qquad x^* = \eta P_x^* + \eta_N N^*,$$

$$(12) \qquad x^* = n^* + x_n^*,$$

$$(13) \qquad [(\eta/(\theta + \eta)) - (\theta/(\theta + \eta))\gamma_{P_X}]P_x^* - (\theta/(\theta + \eta))\gamma_N N^* + (\theta/(\theta + \eta))(1 + \gamma_{xn})x_n^* = \omega_a P_a^* + \omega_b P_b^*,$$

$$(14) \qquad P_x^* - (\theta/\eta)x_n^* - ((\theta + \eta)/\eta)\omega_a P_a^* - ((\theta + \eta)/\eta)\omega_b P_b^* = 0,$$

$$(15) \qquad a_n^* = \omega_b\sigma P_b^* - \omega_b\sigma P_a^* + x_n^*,$$

$$(16) \qquad b_n^* = \omega_a\sigma P_a^* - \omega_a\sigma P_b^* + x_n^*,$$

$$(17) \qquad a^* = n^* + a_n^*,$$

$$(18) \qquad b^* = n^* + b_n^*,$$

$$(19) \qquad P_a^* = (1/e_a)a^* + e_W W^*,$$

$$(20) \qquad P_b^* = (1/e_b)b^* + e_T T^*;$$

where asterisks denote proportional changes (i.e., $v^* \equiv \Delta v/v$), ω_a and ω_b are cost shares, σ is the elasticity of substitution between inputs in the production of the retail product, e_a and e_b are input-supply elasticities, η_N is the elasticity of $D(\cdot)$ with respect to N, e_w is the elasticity of $h(\cdot)$ with respect to W, and e_T is the elasticity of $g(\cdot)$ with respect to T. The terms γ_j, $j \in \{P_x, N, x_n\}$,

are elasticities derived from second-order differentiation of the demand and conjectural-variations functions with respect to the three arguments: P_x, N, and x_n.[7]

It is instructive to note the consistency of the above framework with that of Gardner (p. 400, equations (12)–(14)). Specifically, taking $\theta = 0$, the cost shares, ω_a and ω_b, reduce to Gardner's revenue shares, S_a and S_b, through the respective relationships $\omega_a = S_a((\theta + \eta)/\eta)$ and $\omega_b = S_b((\theta + \eta)/\eta)$. In this case, equation (14), which represents the entry condition, is an exact replication of equation (13) and is, therefore, redundant. This reveals the well-known indeterminacy of firm numbers in the perfectly competitive, constant-returns case.

Empirical Assumptions

Several assumptions are now introduced that will be used in the empirical section that follows. These assumptions facilitate construction of tests of the null hypothesis of perfect competition and are relevant in this context because of their use in previous analyses of food-marketing systems.

The first assumption pertains to the retail-demand shift variable. Following Wohlgenant, N is expressed in percent-change terms as $N^* = \Sigma_j e_{xj} P_j^* + e_{xy} Y^* + POP^*$, where P_j and e_{xj}, $j \in \{1, 2, \ldots, m; j \neq x\}$, denote the prices and the cross-price elasticities of other goods consumed; Y and e_{xy} represent per-capita disposable income and the income elasticity of demand; and POP is the total consuming population. This specification implies that the terms η_N and γ_N are both equal to one.

The second relevant assumption is that farm-commodity supplies are exogenous. This is appropriate because Wohlgenant (fn. 5, p. 248) finds evidence that these supplies are predetermined over the annual periodicity of the data. The assumption is invoked by deleting equation (19) and considering a^* to be exogenous.

The third assumption is that the supply of nonfarm inputs to the food industry is perfectly elastic. This is Gardner's long-run, nonspecific-factor case to which previous empirical work has restricted attention (e.g., Freebairn, Davis, and Edwards; Alston and Scobie; Holloway). In the current investigation, the assumption is a significant one that considerably simplifies several comparative-static expressions. It is invoked by deleting equation (20) and considering P_b^* to be exogenous.

Comparative Statics on the Retail-Farm Price Ratio

With the empirical assumptions in place, consider expressions of the form: $E_{R,z} \equiv E_{Px,z} - E_{Pa,z} \equiv (P_x^*/z^*) - (P_a^*/z^*)$. These expressions denote Gardner's elasticities of the retail-farm price ratio, $R = P_x/P_a$, with respect to the three exogenous variables $z \in \{N, a, P_b\}$. These are, respectively:

$$E_{R,N} = [(2 + \gamma_{xn})\omega_a + (\theta/(\theta + \eta))\sigma\omega_b]/\Phi - [(2 + \gamma_{xn})(\eta/(\theta + \eta)) - (\theta/(\theta + \eta))\gamma_{Px} + (\theta\eta/(\theta + \eta))]/\Phi, \tag{21}$$

$$E_{R,a} = - [(2 + \gamma_{xn})\omega_a]/\Phi + [(2 + \gamma_{xn})(\eta/(\theta + \eta)) - (\theta/(\theta + \eta))\gamma_{Px}]/\Phi, \tag{22}$$

$$E_{R,Pb} = [(2 + \gamma_{xn})\sigma\omega_b]/\Phi - [(2 + \gamma_{xn})\eta + [(\eta/(\theta + \eta))(2 + \gamma_{xn}) - (\theta/(\theta + \eta))\gamma_{Px}]\sigma]\omega_b/\Phi, \tag{23}$$

where $\Phi \equiv [(\eta/(\theta + \eta))(2 + \gamma_{xn}) - (\theta/(\theta + \eta))\gamma_{Px}]\sigma\omega_b - \eta\omega_a(2 + \gamma_{xn})$.

The first terms on the righ-hand sides of (21)–(23) represent the respective effects of N, a, and P_b on P_x; the second terms correspond to effects on P_a. Each of these is observable given data on farm and retail prices and on the three exogenous variables. The task ahead is to derive potentially refutable propositions across the right-hand sides of (21)–(23) that follow from the particular case: $\theta = 0$. Before deriving these, consider the simulation results presented in figure 2.

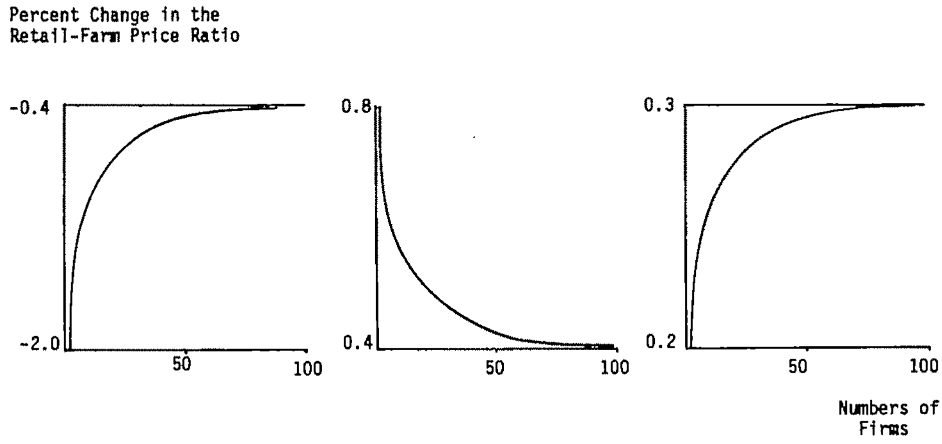
Figures 2a–2c depict movements in the retail-farm price ratio brought about by respective shifts in (*a*) retail demand, (*b*) farm commodity supply, and (*c*) marketing input supply. The results are derived for a hypothetical food industry which is characterized by the parameter values: $\eta = -0.75$, $\sigma = 0.25$, $\omega_a = 0.75$, and $\omega_b = 0.25$. In addition, for this specific example it is as-

[7]The specific definitions are

$$\gamma_{Px} \equiv (\partial^2 D(\cdot)/\partial P_x^2)(P_x/(\partial D(\cdot)/\partial P_x)),$$

$$\gamma_N \equiv (\partial^2 D(\cdot)/\partial P_x \partial N)(N/(\partial D(\cdot)/\partial P_x)), \text{ and}$$

$$\gamma_{xn} \equiv (\partial^2 K(\cdot)/\partial x_n^2)(x_n/(\partial K(\cdot)/\partial x_n)).$$



(*a*) Retail demand (*b*) Farm commodity supply (*c*) Marketing input supply

Figure 2. Movements in the ratio

sumed that each firm behaves as a Cournot competitor.[8]

In the Cournot case, the assumed value for the demand elasticity makes two firms viable in the initial equilibrium, but not one. With two firms, a 1.0% increase in demand causes the ratio to fall by approximately 2.0%. The reduction becomes successively smaller as the number of firms is increased and, in the limit as n approaches infinity, the adjustment approaches the result obtained under perfect competition: −0.4%. For the parameter values considered, the competitive result is approached fairly rapidly, and about ten firms provide a rather good approximation to the competitive case. In contrast to the effects of an increase in demand, an increase in supply of the farm commodity causes the ratio to rise in all cases, but by successively smaller amounts as the number of firms is increased. Specifically, a 1.0% increase in supply causes the ratio to rise by approximately 0.8% in the duopoly case, but by 0.4% in the competitive case. In both the demand- and the supply-shift cases, the effect of competition is to reduce volatility in the ratio. This contrasts with the results corresponding to an increase in the price of marketing services. In this case, the ratio rises by successively greater amounts as the number of firms in the initial equilibrium is increased. However, approximately ten firms again generate a result that is close to the limit of perfect competition.

Although the simulation results are valid only for this particular example, they illustrate an important observation that provides the basis for a test of perfect competition using observed movements in the retail-farm price ratio: Under perfect competition the proportional effects on the ratio of shifts in retail demand and farm-commodity supply are equal in magnitude but opposite in sign. This finding is illustrated in figures 2a and 2b. With 1.0% increases in demand and supply, respectively, the values of the relevant elasticities under perfect competition are −0.4 in the case of a demand shift and +0.4 in the case of a supply shift. The result is useful empirically because it implies that a test of competition reduces to a test of the validity of a linear restriction imposed across the coefficients of N^* and a^* in a regression on R^*. As an alternative, the test can also be applied in independent regressions on retail- and farm-price movements. To investigate these conditions in more detail, the above discussion is formalized as follows.

PROPOSITION: *Necessary and (almost) sufficient conditions for perfect competition in the retail food markets are (i)* $E_{pa,N} = -E_{pa,a}$, *(ii)* $E_{px,N} = -E_{px,a}$, *and (iii)* $E_{R,N} = -E_{R,a}$.

Proof: To prove necessity of (*i*)–(*iii*), simply note in (21) and (22) that the condition $\theta = 0$ implies conditions (*i*)–(*iii*), hence the latter are necessary for the former. The sufficiency of condition (*i*) is noted by considering the second terms on the right-hand sides of (21) and (22). By defining $F(\cdot) \equiv (2 + \gamma_{xn})(\eta/(\theta + \eta)) - (\theta/(\theta + \eta))\gamma_{Px}$, one has $E_{Pa,N} = F(\cdot)/\Phi + (\theta\eta/(\theta$

[8] This assumption enables the results to be synthesized assuming that different numbers of firms support the initial equilibrium. It is important to note, however, that none of the theoretical results of the paper depend on the assumption of Cournot behavior.

$+ \eta))/\Phi$ and $-E_{Pa,a} = F(\cdot)/\Phi$. Because the assumed uniqueness of the equilibrium rules out $\Phi = 0$, in the empirically significant case in which Φ is not infinite, it follows that $E_{Pa,N} = -E_{Pa,a}$ is sufficient for the result $\theta\eta = 0$, which implies either $\theta = 0$ or $\eta = 0$, or both. However, because the case of perfectly inelastic demand has already been shown to imply $\theta = 0$, it follows that condition (*i*) is sufficient for competition. The sufficiency of condition (*ii*) can be derived similarly by defining $J(\cdot) \equiv (2 + \gamma_{xn})\omega_a$ and writing $E_{Px,N} = J(\cdot)/\Phi + (\theta/(\theta + \eta))\sigma\omega_b/\Phi$ and $-E_{Px,a} = J(\cdot)/\Phi$. Hence, again assuming nonextreme values for Φ, $E_{Px,N} = -E_{Px,a}$ is sufficient for $(\theta/(\theta + \eta))\sigma\omega_b = 0$. Because $\omega_b = 0$ is ruled out by assumption, it follows that either $\theta = 0$ or $\sigma = 0$, or both. The available empirical evidence (Wohlgenant, table 3, p. 250) suggests that $\sigma \neq 0$. However, in the unlikely case where $\sigma = 0$, another restriction is implied; namely, $E_{Px,Pb} = 0$, which is obtained from equation (23). Hence, the joint conditions $E_{Px,N} = E_{Px,a}$ and $E_{Px,Pb} \neq 0$ constitute sufficient conditions for $\theta = 0$. It follows, therefore, from Wohlgenant's results that the single condition $E_{Px,N} = -E_{Px,a}$ is "almost sufficient" for competition. Finally, that condition (*iii*) is almost sufficient for $\theta = 0$ follows from the previous discussion and the fact that $E_{R,z} \equiv E_{Px,z} - E_{Pa,z}$, $z \in \{N, a, Pb\}$.

Empirical Model and Results

The above observations provide the bases for three alternative tests which are now applied to data on the marketing systems for the eight commodity groups considered by Wohlgenant. Following Wohlgenant, instantaneous relative changes in the variables, $v^* \equiv \Delta v/v$, are replaced by first differences in the logarithms, $v_t^* \equiv ln(v_t) - ln(v_{t-1})$, where the subscripts t and $t - 1$ refer to consecutive time periods. Using this notation, the three equations to be estimated for each of the groups are

$$(24) \quad R_t^* = \beta_{Rx}N_t^* + \beta_{Ra}a_t^* + \beta_{Rb}P_{bt}^* + \epsilon_{Rt},$$

$$(25) \quad P_{xt}^* = \beta_{xx}N_t^* + \beta_{xa}a_t^* + \beta_{xb}P_{bt}^* + \epsilon_{xt},$$

$$(26) \quad P_{at}^* = \beta_{ax}N_t^* + \beta_{aa}a_t^* + \beta_{ab}P_{bt}^* + \epsilon_{at},$$

where β_{jk}, $j \in \{R, x, a\}$ and $k \in \{x, a, b\}$, are coefficients to be estimated; and ϵ_{jt}, $j \in \{R, x, a\}$, are disturbance terms which are assumed to be normally distributed. In view of the equilibrium framework, there is a legitimate presumption that these disturbances are contemporaneously correlated. In fact, in any time period only two of these three effects are independent because of the identity: $R_t^* \equiv P_{xt}^* - P_{at}^*$. However, in the absence of cross-equation restrictions and with the same independent variables appearing on the right-hand sides of (24)–(26), the ordinary-least-squares estimator is applied to each equation individually.

A question of interest is whether the validity of any of the null hypotheses can be inferred directly from Wohlgenant's previous work. For example, the restrictions $\beta_{jx} = -\beta_{ja}$, $j \in \{x, a\}$, are imposed as equations (14a) and (14b) in the estimations that yield his table 2 (p. 249). Unfortunately, Wohlgenant's results cannot be used directly because a zero-homogeneity restriction has been imposed on prices by deflating all nominal variables by the consumer price index. This deflation, which yields efficient estimates under perfect competition, cannot be inferred from the more general model, and thus equations (24)–(26) are estimated with prices in their nominal forms.

The data used are annual observations for the period 1955–83 on retail and farm prices, quantities of farm commodities, and an index of the price of marketing inputs. A detailed description of these data is contained in Wohlgenant's recent paper and the literature cited therein.

Table 1 presents unrestricted estimates of (24)–(26) for each of the eight commodity groups. Most of the signs of the coefficients conform to those predicted by the conceptual model. In general, farm commodity supplies have a significant, negative impact on farm and retail prices, and the retail-demand shift variables have a significantly positive impact. As indicated by the Durbin-Watson statistics, first-order autocorrelation does not appear to be a problem.

Table 2 presents estimates of (24)–(26) with the restrictions imposed that $\beta_{jx} = -\beta_{ja}$, $j \in \{R, x, a\}$. Under H_0: $\theta = 0$, critical values of the F-statistic are $F_{0.05} = 4.24$ and $F_{0.01} = 7.77$. The test cannot be rejected at either level of significance in any single equation.

These results are sufficient to confirm competition only in the case of the farm-price equation. The sufficiency of $\beta_{jx} = -\beta_{ja}$, $j \in \{R, x\}$, is investigated by testing the null hypothesis H_0: $\sigma = 0$ by imposing the single restriction $\beta_{xb} = 0$. Table 3 presents the results of these restricted estimations. Under H_0: $\sigma = 0$, critical values of the F-statistic are $F_{0.05} = 4.22$ and $F_{0.01} = 7.72$. This restriction is rejected at the 5% significance level for all commodities except two: beef and veal, and pork. It is rejected at the 1% level

Table 1. Unrestricted Estimates of the Ratio, Retail Price, and Farm Price Equations

		Elasticities with Respect to				
Commodity	Price	Retail Demand	Farm Commodity Supply	Marketing Input Costs	R^2	D-W
Beef and veal	Ratio	−0.484	0.465	0.534	0.417	1.986
		(−2.474)	(3.146)	(2.670)		
	Retail	0.666	−0.973	0.302	0.738	2.121
		(2.894)	(−5.595)	(1.286)		
	Farm	1.150	−1.438	−0.231	0.629	2.078
		(3.136)	(−5.190)	(−0.618)		
Pork	Ratio	−0.575	1.026	0.328	0.708	2.385
		(−1.529)	(7.543)	(1.026)		
	Retail	1.137	−0.912	0.103	0.853	2.012
		(4.409)	(−9.781)	(0.468)		
	Farm	1.713	−1.938	−0.226	0.868	1.922
		(3.852)	(−12.057)	(−0.596)		
Poultry	Ratio	−1.027	1.492	−0.091	0.449	1.583
		(−3.622)	(3.842)	(−0.290)		
	Retail	1.276	−1.548	0.413	0.800	1.624
		(8.477)	(−7.485)	(2.468)		
	Farm	2.303	−3.040	0.504	0.757	1.832
		(7.464)	(−7.196)	(1.474)		
Eggs	Ratio	−2.867	1.705	0.672	0.136	2.571
		(−1.607)	(1.507)	(1.533)		
	Retail	4.156	−4.824	−0.583	0.523	2.282
		(2.686)	(−4.914)	(−1.534)		
	Farm	7.023	−6.529	−1.256	0.420	2.554
		(2.664)	(−3.904)	(−1.938)		
Dairy	Ratio	−0.494	0.579	0.043	0.197	2.082
		(−1.301)	(2.016)	(0.304)		
	Retail	0.237	−0.733	0.750	0.853	2.577
		(0.654)	(−2.671)	(5.520)		
	Farm	0.732	−1.312	0.706	0.725	2.245
		(1.182)	(−2.805)	(3.051)		
Processed fruits and vegetables	Ratio	0.068	−0.322	0.139	0.251	2.236
		(0.351)	(−2.585)	(1.187)		
	Retail	−0.041	−0.379	0.987	0.683	2.159
		(−0.131)	(−1.902)	(5.253)		
	Farm	−0.109	−0.057	0.847	0.666	2.574
		(−0.388)	(−0.319)	(5.010)		
Fresh fruit	Ratio	0.006	−0.775	0.378	0.278	2.564
		(0.014)	(−2.879)	(2.136)		
	Retail	−0.055	−0.783	0.983	0.456	2.409
		(−0.108)	(−2.364)	(4.506)		
	Farm	−0.061	−0.008	0.604	0.217	2.612
		(−0.104)	(−0.021)	(2.417)		
Fresh vegetables	Ratio	−1.276	2.008	0.232	0.516	2.250
		(−1.749)	(4.552)	(0.817)		
	Retail	0.955	0.105	0.462	0.445	2.506
		(1.147)	(0.209)	(1.426)		
	Farm	2.231	−1.903	0.230	0.539	2.499
		(2.764)	(−3.898)	(0.733)		

Note: Values in parentheses are t-statistics. The R^2 value is obtained from a regression of predicted values on actual values.

for dairy, processed fruits and vegetables, fresh fruits, and fresh vegetables. Hence, the restriction $\sigma = 0$ is a stringent one for all except the former two groups, and for the remaining groups it implies that the nonrejection of $\beta_{jx} = -\beta_{ja}$, $j \in \{R, x, a\}$, is sufficient to infer competition. For the beef and veal, and pork groups, the results are less conclusive, although the nonrejection of $\beta_{ax} = -\beta_{aa}$ in both cases suggests that any departures from competition have been relatively insignificant.[9]

[9] It is insightful to reconcile the findings in the beef and veal group with those of Schroeter, who studied the U.S. beef-packing industry over the period 1951–83. He found small but statistically significant departures from competition in both the retail product and the farm commodity markets. One possible explanation for the

Table 2. Estimates of the Ratio, Retail-Price, and Farm-Price Equations Under the Null Hypothesis of Perfect Competition in Marketing

Commodity	Price	F H_0. $\theta = 0$	Elasticities with Respect to: Retail Demand	Farm Commodity Supply	Marketing Input Costs	R^2	D-W
Beef and veal	Ratio	0.01	−0.471 (−3.977)	0.472 (3.977)	0.523 (3.756)	0.416	1.998
	Retail	1.20	0.864 (6.047)	−0.864 (−6.047)	0.121 (0.723)	0.725	1.945
	Farm	0.42	1.335 (5.958)	−1.335 (−5.958)	−0.401 (−1.527)	0.623	1.960
Pork	Ratio	1.27	−0.974 (−7.575)	0.974 (7.575)	0.625 (3.419)	0.693	2.436
	Retail	0.68	0.938 (10.765)	−0.938 (−10.765)	0.251 (2.028)	0.849	2.087
	Farm	0.23	1.912 (12.841)	−1.912 (−12.841)	−0.374 (−1.765)	0.867	1.924
Poultry	Ratio	1.49	−1.147 (−4.267)	1.147 (4.267)	0.188 (0.862)	0.416	1.749
	Retail	1.80	1.346 (9.349)	−1.346 (−9.349)	0.250 (2.139)	0.785	1.474
	Farm	3.17	2.492 (8.286)	−2.492 (−8.286)	0.062 (0.253)	0.726	1.944
Eggs	Ratio	0.40	−1.955 (−1.864)	1.955 (1.864)	0.494 (1.482)	0.122	2.567
	Retail	0.18	4.680 (5.167)	−4.680 (−5.167)	−0.686 (−2.382)	0.519	2.179
	Farm	0.03	6.636 (4.312)	−6.636 (−4.312)	−1.180 (−2.412)	0.419	2.580
Dairy	Ratio	0.04	−0.551 (−2.233)	0.551 (2.233)	0.064 (0.694)	0.195	2.028
	Retail	1.50	0.571 (2.351)	−0.571 (−2.351)	0.625 (6.860)	0.844	2.328
	Farm	0.71	1.122 (2.753)	−1.122 (−2.753)	0.561 (3.665)	0.717	2.012
Processed fruits and vegetables	Ratio	1.81	0.274 (2.261)	−0.274 (−2.261)	0.026 (0.308)	0.196	2.273
	Retail	1.93	0.300 (1.543)	−0.300 (−1.543)	0.799 (6.016)	0.658	2.066
	Farm	0.37	0.026 (0.153)	−0.026 (−0.153)	0.773 (6.663)	0.660	2.507
Fresh fruit	Ratio	2.71	0.572 (2.314)	−0.572 (−2.314)	0.282 (1.635)	0.199	2.698
	Retail	2.13	0.562 (1.867)	−0.562 (−1.867)	0.878 (4.173)	0.409	2.212
	Farm	0.01	−0.010 (−0.031)	0.010 (0.031)	0.595 (2.572)	0.216	2.590
Fresh vegetables	Ratio	0.77	−1.820 (−4.737)	1.820 (4.737)	0.438 (2.757)	0.501	2.121
	Retail	1.24	0.167 (0.378)	−0.167 (−0.378)	0.760 (4.157)	0.417	2.524
	Farm	0.13	1.987 (4.734)	−1.987 (−4.734)	0.322 (1.859)	0.537	2.557

Note: Values in parentheses are t-statistics. The R^2 value is obtained from a regression of predicted values on actual values. Under H_0, $\theta = 0$, critical values of the F-statistic are: $F_{0.05}(1/25) = 4.24$ and $F_{0.01}(1/25) = 7.77$.

difference in results is that Schroeter imposed, a priori, $\sigma = 0$; hence, the conjectural elasticities in both markets are restricted to be the same. The vast differences in the structures of retail and farm commodity markets leads one to suspect that this practice may impart a bias in estimates of degrees of market power.

Concluding Comments

This paper has developed a conceptual model for the analysis of imperfect competition in the food industries. The model is motivated by an

Table 3. Estimates of the Retail-Price Equations Under the Null Hypothesis of Leontief Technologies in Marketing

		Elasticities with Respect to			
Commodity	F $H_0.\ \sigma = 0$	Retail Demand	Farm Commodity Supply	R^2	D-W
Beef and veal	0.52	0.927 (8.325)	−0.927 (−8.325)	0.720	1.966
Pork	4.11	0.991 (11.300)	−0.991 (−11.300)	0.826	1.736
Poultry	4.57	1.366 (8.943)	−1.366 (−8.943)	0.748	1.239
Eggs	5.67	3.306 (4.370)	−3.306 (−4.370)	0.414	2.263
Dairy	47.05	1.713 (5.896)	−1.713 (−5.896)	0.563	0.764
Processed fruits and vegetables	36.20	0.682 (2.448)	−0.682 (−2.448)	0.182	1.015
Fresh fruit	17.42	0.225 (0.611)	−0.225 (−0.611)	0.014	1.270
Fresh vegetables	17.28	0.505 (0.917)	−0.505 (−0.917)	0.030	1.410

Note: Values in parentheses are t-statistics. The R^2 value is obtained from a regression of predicted values on actual values. Under H_0. $\sigma = 0$, critical values of the F-statistic are: $F_{0.05}(1/26) = 4.22$ and $F_{0.01}(1/26) = 7.72$.

extensive literature that focuses on noncompetitive behavior in these industries and by a need to derive formal relationships between food market structure, food industry conduct, and food market performance.

The theoretical development has focused on the determinants of conduct as specified through the magnitudes of firms' conjectural elasticities. The magnitudes of these elasticities are determined by the multiplicative value of two market-structure variables; namely, the responsiveness of the demand for firms' products and the size of the fixed costs they incur upon entering the market. These two factors can generate equilibria that are similar to but may diverge from the one obtained under perfect competition.

The empirical results suggest that, during the period 1955–83, departures from competition in the retail markets of the major food groups have been relatively insignificant. That is, the observed outcomes in these groups are not statistically different from the one obtained under perfect competition.

To derive these findings, several restrictions were imposed on the types of markets under consideration. Specifically, it was assumed that the product in question is homogenous, that adjustments to new equilibria are instantaneous, and that those adjustments occur in a closed-economy setting in the absence of government intervention. In reality, of course, these assumptions are violated to varying degrees, and it is useful to consider the results in the light of the model's simplifications.

The markets for some food products are heterogenous with substantial product differentiation. This type of structure lends itself to a number of alternative forms of noncompetitive behavior such as entry deterrence through product proliferation and excessive levels of promotion (Schmalensee, Connor, Zellner). Although the specific effects of these activities remain an open question, an issue that can be addressed within the current framework is how the qualitative results may be affected by the introduction of differentiated products. The answer can be obtained in part by noting a duality between equilibria in a homogenous-products setting and equilibria in a differentiated-products model (Kamien and Schwartz, pp. 205–6). In particular, there is a monotonic relationship between conjectures, prices, and quantities in both equilibria. Thus, although the homogenous-products model may be incapable of predicting precise effects, the direction of many effects may be explicable within the current framework.

A more general criticism of the conjectural-variations model is that it is formulated within a static framework in which the concepts of conjectures and responses have only an instantaneous interpretation (Dixit). Modeling the food

industries in a dynamic setting may be a fruitful extension for two reasons. First, it is an appropriate step in overcoming a general criticism of the current framework. Second, and perhaps more important, it would allow closer scrutiny of the effects of potential entry, and strategies to deter such entry, on incumbent firms' conduct and the long-run performance of food markets. The present model considers entry in a rather simplified manner that prohibits the persistence of strictly positive profits. Such profits have been shown to exist in a dynamic variant of the current model (Reynolds). In view of the lags inherent in many agricultural production processes, the dynamics of conduct in the food industries may be extremely important in explaining price movements at both the farm and the retail levels.[10]

Finally, government intervention and international trade play important roles in many food-marketing systems. The analytical effects of interventions such as price supports or production controls can be investigated with little additional difficulty by applying methods analogous to Gardner's (pp. 403–5). In contrast, the introduction of a foreign marketing sector may bring enormous complexities. The model presented in the present paper should at least assist in directing efforts to these more complex analyses of imperfect competition in the food industries.

[Received May 1989; final revision received January 1991.]

References

Allen, R. G. D. *Mathematical Analysis for Economists*. London: Macmillan & Co., 1938.

Alston, J. M., and G. M. Scobie. "Distribution of Research Gains in Multistage Production Systems: Comment." *Amer. J. Agr. Econ.* 65(1983):353–56.

Appelbaum, E. "The Estimation of the Degree of Oligopoly Power." *J. Econometrics* 19(1982):287–99.

Connor, J. M. "Food Product Proliferation: A Market Structure Analysis." *Amer. J. Agr. Econ.* 63(1981):607–17.

Connor, J. M., R. T. Rogers, B. W. Marion, and W. F. Mueller. *The Food Manufacturing Industries: Structure, Strategies, Performance, and Policies*. Lexington KY: D. C. Heath and Co., 1985.

Dixit, A. "Comparative Statics for Oligopoly." *Int. Econ. Rev.* 27(1986):107–22.

[10]For an interesting empirical application of dynamic oligopoly concepts, see Karp and Perloff.

Fisher, B. S. "A Change in Marketing Charges: Who Loses What?" *Amer. J. Agr. Econ.* 63(1981):261–63.

Freebairn, J. W., J. S. Davis, and G. W. Edwards. "Distribution of Research Gains in Multistage Production Systems: Reply." *Amer. J. Agr. Econ.* 65(1983):357–59.

Gardner, B. L. "The Farm–Retail Price Spread in a Competitive Food Industry." *Amer. J. Agr. Econ.* 57(1975):399–409.

Gisser, M. "Welfare Implications of Oligopoly in U.S. Food Manufacturing." *Amer. J. Agr. Econ.* 64(1982):616–24.

Gollop, F. M., and M. J. Roberts. "Firm Interdependence in Oligopolistic Markets." *J. Econometrics* 10(1979):313–31.

Holloway, G. J. "Distribution of Research Gains in Multistage Production Systems: Further Results." *Amer. J. Agr. Econ.* 71(1989):338–43.

Just, R., and W. S. Chern. "Tomatoes, Technology, and Oligopsony." *Bell J. Econ.* 11(1980):584–602.

Kamien, M. I., and N. L. Schwartz. "Conjectural Variations." *Can. J. Econ.* 16(1983):191–211.

Karp, L. S., and J. M. Perloff. "Dynamic Oligopoly in the Rice Export Market." *Rev. Econ. Statist.* 71(1989):462–70.

Kilmer, R. L. "The Economic Efficiency of Alternative Exchange Mechanisms." *Economic Efficiency in Agricultural and Food Marketing*, ed. R. L. Kilmer and W. J. Armbruster, pp. 134–49. Ames: Iowa State University Press, 1987.

Lopez, R. E. "Measuring Oligopoly Power and Production Responses of the Canadian Food Processing Industry." *J. Agr. Econ.* 35(1984):219–30.

Mueller, W. F., and B. W. Marion. "Market Power and Its Control in the Food System." *Amer. J. Agr. Econ.* 65(1983):855–63.

Quirmbach, H. C. "Comparative Statics for Oligopoly: Demand Shift Effects." *Int. Econ. Rev.* 29(1988):451–58.

Reynolds, S. "Limit Pricing, Conjectural Variations, and Entry." *Econ. Letters* 9(1982):195–99.

Schmalensee, R. "Entry Deterrence in the Ready-to-Eat Breakfast Cereal Industry." *Bell. J. Econ.* 9(1978):305–27.

Schroeter, J. R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Rev. Econ. Statist.* 70(1988):158–62.

Sumner, D. A. "Measurement of Monopoly Power: An Application to the Cigarette Industry." *J. Polit. Econ.* 89(1981):1010–19.

Sullivan, D. "Testing Hypotheses about Firm Behavior in the Cigarette Industry." *J. Polit. Econ.* 93(1985):586–98.

Wohlgenant, M. K. "Demand for Farm Output in a Complete System of Demand Equations." *Amer. J. Agr. Econ.* 71(1989):241–52.

Zellner, J. A. "A Simultaneous Analysis of Food Industry Conduct." *Amer. J. Agr. Econ.* 71(1989):105–15.

Marketing Margins, Market Power, and Price Uncertainty

John Schroeter and Azzeddine Azzam

This paper provides a conceptual and empirical framework for analyzing marketing margins in a noncompetitive food-processing industry facing output price uncertainty. The framework allows the decomposition of observed margins into components reflecting the marginal cost of the processing industry, oligopoly/oligopsony price distortions, and an output price risk component. The empirical procedure is applied to a time series of spreads between wholesale pork prices and farm prices of market hogs. The principal finding is that, while farm/wholesale margins are more consistent with competitive performance now than they were fifteen years ago, the output price risk component persisted throughout the sample period.

Key words: hog prices, marketing margins, market power, risk.

In their 1985 paper, Brorsen et al. (BCGS) investigate the effects of output price uncertainty on the price spread in an agricultural marketing channel. Their theoretical model adapts Sandmo's treatment of firm behavior under uncertainty to Gardner's model of price spread determination in competitive food industries. Within this framework, BCGS derive a positive relationship between the marketing margin and a measure of price risk and confirm it using data from the U.S. wheat-milling industry.

BCGS's assumptions of competitive conduct by marketing firms may not hold in all settings. In this paper, we, too, explore the connection between output price uncertainty and marketing margins but in the important oligopoly/oligopsony setting in which marketing firms may exercise some power over price in the markets for the agricultural input and/or the food output. Our model also has two main antecedents: Leland's extension of Sandmo's analysis to the case of a firm facing an uncertain but downward-sloping demand curve and the method of modeling oligopoly in which conjectural variations are used to parametrize the market's degree of competitiveness.[1] Our approach differs further from BCGS in the technique for measuring output price risk. Instead of basing the measure on past changes in price, we follow Aradhyula and Holt in using estimates of conditional forecast variances from an autoregressive, conditionally heteroscedastic (ARCH) time-series model of price.

Our model yields an equilibrium condition for the risk-averse, expected utility-maximizing food-processing firm that equates the expected margin with the sum of four components: marginal processing cost, oligopoly and oligopsony price distortions, and a component reflecting the effects of the firm's optimal adjustment to price risk. For each of the components, theory implies certain telltale characteristics in terms of their relationships to exogenous factors. These characteristics serve as the key to empirical identification of the individual components. The margin decomposition, together with input supply and output demand functions, forms an econometric model which is estimated using data from the U.S. hog-packing industry.[2] Indeed, the BCGS assumption of perfect competition would seem to be inappropriate for this particular case. Growing concentration in meat pack-

John Schroeter is an associate professor, Department of Economics, Iowa State University, and Azzeddine Azzam is an assistant professor, Department of Agricultural Economics, University of Nebraska.

This is University of Nebraska Agricultural Experiment Station Journal Article No. 9197.

The authors thank Tim Parks, Joe Atwood, Glenn Helmers, Gene Futrell, Frances Antonovitz, and two anonymous reviewers for helpful comments and suggestions, and Clement Ward for providing some of the data.

[1] Examples of empirical applications of conjectural variation models to food processing include Just and Chern, Lopez, Schroeter, Schroeter and Azzam, and Azzam and Pagoulatos. Bresnahan provides an extensive bibliography.

[2] In an earlier paper, Azzam, Pagoulatos, and Schroeter estimated decompositions of the farm/wholesale pork margin into cost and market power components but did not consider possible effects of price uncertainty.

ing means that one must consider the possibility of noncompetitive conduct in the industry. Whether output price uncertainty is a significant factor is less clear a priori. Determination of the comparative magnitudes of the margin components is thus an empirical task.

The Theoretical Model

A large number of food processors use a single homogenous agricultural input to produce a single homogenous output.[3] The production process requires nonagricultural inputs (labor, energy, transportation, etc.) that are purchased at prices that individual firms take as given. The firms may possess power over price, however, in the regional markets in which the agricultural input is purchased or the national market in which output is sold. Because of a production time lag, firms making input decisions are uncertain about the output price. The possibility of market power means that individual firms may perceive themselves to have some ability to move output (input) market equilibrium along a demand (supply) curve. In the present framework, the output price uncertainty is modeled as uncertainty about the position, but not the slope, of the demand curve. Thus, firms with a degree of monopoly power do not know what the realized output price will be but are assumed to know the marginal effects of changes in their own outputs on expected price. Modeling output price uncertainty in this way leads to an expression for the margin in which the four components are additively separable.

The industry is geographically dispersed over several input supply regions, each of which contains several firms. Each of the firms operating in region j, say, faces an agricultural input supply function given by

(1) $$w_j = G_j(Q_j),$$

where Q_j and w_j are the supply quantity and price, respectively, in region j. The form of (1) assumes that input price is a nonrandom function of regional quantity. This reflects the assumption that the actual input price is observed at the time production decisions are made. Demand in the national output market, on the other hand, is described by

(2) $$p = H(Q) + u,$$

where Q and p are demand quantity and price, respectively, and u is a zero mean random variable distributed independently of Q. Denote the (constant) variance of u by σ_p^2. Assuming that the production relationship between the agricultural input and output is one of fixed proportions, it is permissible to interpret output and input quantities as being directly comparable. For example, one could measure input quantity in units of the weight of input required to produce one pound of output.

Denote the processing cost function of the ith firm in the jth region by $c_{ij}(q_{ij}, v)$, where q_{ij} is the firm's food output/agricultural input quantity and v is the vector of prices of nonagricultural inputs. The firm's profit function is given by

$$\pi_{ij} = (p - w_j)q_{ij} - c_{ij}(q_{ij}, v).$$

For a given choice of q_{ij}, π_{ij} is a random variable because p is a random variable. The firm's objective is to maximize the expected utility of profit where the utility function is assumed to be of the constant absolute risk aversion type: $U(\pi_{ij}) = -e^{-\lambda_{ij}\pi_{ij}}$. Assuming u is normally distributed, the first-order condition is

$$E[p] - w_j = \frac{\partial c_{ij}}{\partial q_{ij}} - q_{ij}\left(\frac{dE[p]}{dQ}\right)\left(\frac{\partial Q}{\partial q_{ij}}\right) + q_{ij}\left(\frac{dw_j}{dQ_j}\right)\left(\frac{\partial Q_j}{\partial q_{ij}}\right) + \lambda_{ij}q_{ij}\sigma_p^2.$$

This equation can be rewritten as

(3) $$E[M_j] = C_{ij} - Q\eta^{-1}\theta_{1ij} + Q\epsilon_j^{-1}\theta_{2ij} + Q\delta_{ij}\sigma_p^2,$$

where M_j is $p - w_j$, the margin faced by firms in region j; C_{ij} is $\partial c_{ij}/\partial q_{ij}$, the marginal processing cost of firm i in region j; η is $dQ/dE[p]$, the slope of the expected product demand curve; ϵ_j is $(dQ_j/dw_j)(Q/Q_j)$, the slope of input supply in region j times the inverse of region j's national market share; θ_{1ij} is $(\partial Q/\partial q_{ij})(q_{ij}/Q)$, the output market conjectural elasticity of firm i in region j; θ_{2ij} is $(\partial Q_j/\partial q_{ij})(q_{ij}/Q_j)$, the regional input market conjectural elasticity of firm i in region j; δ_{ij} is $\lambda_{ij}(q_{ij}/Q)$, the coefficient of absolute risk aversion times the national market share for firm i in region j; Q_j is $\Sigma_i\, q_{ij}$, the total input/output quantity in region j; and Q is $\Sigma_j Q_j$, the total national input/output quantity.

The conjectural elasticities are indices of the firm's output and input market power. If the firm were a price taker in both of these markets, θ_{1ij} and θ_{2ij} would equal zero, and so, too, would

[3] The single "output" could represent a set of multiple outputs produced in fixed proportions.

the second and third terms on the right-hand side of equation (3). A value of 1 for $\theta_{1ij}(\theta_{2ij})$, on the other hand, would reflect pure monopoly (monopsony) conduct. If the variance of u were zero (no output price uncertainty), the fourth term would be zero. Otherwise, $Q\delta_{ij}\hat{\sigma}_p^2$ is a positive number.[4]

Equation (3) thus implies that the expected marketing margin is the sum of four nonnegative components: marginal processing cost, terms reflecting oligopoly and oligopsony pricing distortions, and an adjustment for the effects of output price uncertainty on a risk-averse, expected utility-maximizing firm's decisions. Assuming that the subjective expectation of price equals the objective expectation for each firm in region j, each faces the same expected margin. So for each, the sum of the four terms on the right-hand side of equation (3) must have the same value. Firms may have different cost functions, perceptions of their own market power, and degrees of risk aversion, however, so the breakdown of the margin, in equilibrium, may differ from firm to firm. Consequently, the construction of any industry-wide counterpart to equation (3) will have to involve averaging of some sort. Assume that the ϵ_j's are the same across regions and equal to the national supply slope, ϵ.[5] Multiply equation (3) by q_{ij}, sum over all regions and over all firms within each region, and divide by Q. The result is

$$(4) \quad M = C - Q\eta^{-1}\theta_1 + Q\epsilon^{-1}\theta_2 + Q\delta\sigma_p^2,$$

where M, C, θ_1, θ_2, and δ are quantity weighted averages of their region- or firm-specific counterparts. Note that the cost component in this expression, C, is a weighted average of firms' marginal costs.

Margins and Output Price Uncertainty in Hog Packing

Equation (4) will be used as a basis for testing the significance of the market power and output price risk components of the farm/wholesale margin for pork. Ward (1988) estimates the 1987 national four-firm concentration ratio for hog slaughter at 36.7%. While this figure is not unusually large relative to other agricultural commodity-processing industries (Nelson), concern about market power persists due to extremely high concentration in the regional markets in which slaughter hogs are purchased. Ward (1988) reports that seven of the ten leading hog slaughter states in 1985 had four-firm concentration ratios of 98% or higher. High concentration in hog packing is responsible for the suspicion that packer margins may reflect not only marginal processing costs but input and, perhaps, output market price distortions, $Q\epsilon^{-1}\theta_2$ and $-Q\eta^{-1}\theta_1$ as well.

The production lag in hog packing exposes firms to output price risk. The lag is quite short to be sure: two or three days for fresh carcass pork and perhaps up to a week for cured products. In the meat-packing industry, the ratio of net earnings to total sales is quite low, however, so even a 1% or 2% fluctuation in output price could cause a substantial percentage change in profit.[6] Price risk, measured by σ_p, might therefore be quite large relative to mean profit per unit. The price effect of firm's adjustment to this profit risk is captured by $Q\delta\sigma_p^2$, the last term in equation (4).

A key assumption in the theoretical model is that the firm does not reduce output price risk through forward contracting. Because inventories are carried for such a short time, no opportunities for perfect time hedges are available from organized futures markets and the basis risk associated with available contracts over the holding period may well be nearly as great as the spot price risk. Hayenga et al. report that there is very little informal forward contracting between hog packers/processors and their customers, with the bulk of wholesale transactions taking place on a formula or negotiated price basis. Of course, this could be interpreted as circumstantial evidence that output price risk is not very important in this industry. On the other hand, one also would expect little forward contracting if firms were subjected to "significant" price risk only from time to time and the transactions costs of sporadic forward contracting were prohibitive. This scenario, involving only periodic spells of high price risk, is roughly consistent with the

[4] In general, that is, for an arbitrary utility function, the form of the fourth term in equation (3) is $-E[U'(\pi_{ij})u]/E[U'(\pi_{ij})]$. Thus, risk neutrality [$U'(\pi_{ij})$ = constant] is another condition under which this term would be zero.

[5] This assumption would hold exactly if the national market supply curve resulted from a straightforward linear aggregation of identical regional supply curves. In that case, if there were ten regions, for example, the slope of national market supply would be ten times the slope of the representative regional supply. Of course, national supply may be less elastic than the sum of regional supplies because the slope of the latter may reflect not only production responses but also producers' opportunities to move the input across region boundaries in response to transport-cost-compensated price differentials. In any event, the assumption that there is a common value of ϵ_j that is identifiable from the national supply curve is necessary for estimation with aggregate data.

[6] Ward (1990), summarizing American Meat Institute survey data, reports that hog packer average net earnings never exceeded 1.6% of sales in the 1979–87 period.

ARCH specification for the error term in the price-forecasting model developed below.

Measurements of σ_p^2, the variance of the conditional forecast of future price, should be based upon a forecast horizon which approximates the production lag faced by firms. For simplicity, we take this to be one week. Data limitations require that the empirical model of which equation (4) will be a part is implemented using quarterly data rather than weekly data. But each quarter's proxy for the value of σ_p^2 will be the quarter's average value of the variance of conditional one-week-ahead forecasts of price. These conditional forecast variances therefore must be estimated using a separate price model based on weekly data.

The National Provisioners report weekly average wholesale price quotations on a variety of fresh pork primal sections. Continuous series for the period 1972–88 were collected for four sections: loins, bellies, hams, and spareribs. A weighted average of these was formed using representative carcass proportions as weights. The resulting weekly wholesale price series, denoted by P_τ for $\tau = 1, 2, \ldots, 884$ (17 years × 52 weeks per year) and measured in units of cents per pound, is the basis for our measurement of price uncertainty.

Engle's ARCH and Bollerslev's GARCH models provide convenient methods for incorporating time-varying conditional forecast variances. The specification of our price-forecasting model began with ordinary least squares regressions of price on sets of lagged prices, and trend and seasonal terms. Using the Akaike Information Criterion (Judge et al., pp. 423–24) as a guide, the regressors listed in equation (5) were selected for inclusion;

$$(5)\quad \begin{aligned} P_\tau = {} & \gamma_0 + \gamma_1 P_{\tau-1} + \gamma_2 P_{\tau-3} + \gamma_3 P_{\tau-4} \\ & + \gamma_4 P_{\tau-6} + \gamma_5 P_{\tau-7} + \gamma_6 P_{\tau-10} \\ & + \gamma_7 T_\tau^2 + \gamma_8 T_\tau^3 + \gamma_9 T_\tau^4 + \gamma_{10} T_\tau^5 \\ & + \gamma_{11} T_\tau^6 + \gamma_{12} T_\tau^7 + \gamma_{13} W_\tau^2 + \gamma_{14} W_\tau^3 \\ & + \gamma_{15} W_\tau^4 + \gamma_{16} W_\tau^5 + \gamma_{17} W_\tau^7 + \zeta_\tau \\ & \text{for } \tau = 11{,}884, \end{aligned}$$

where T_τ is a rescaled time trend ($T_\tau = \tau/100$), W_τ is a rescaled weekly seasonal term [W_τ = (week τ's number within the year)/10], and the ζ_τ's are independently distributed error terms with conditional mean zero and conditional variance h_τ.

A GARCH(p,q) specification for the error variances means that

$$(6)\quad h_\tau = \alpha_0 + \sum_{i=1,q} \alpha_i \zeta_{\tau-i}^2 + \sum_{i=1,p} \beta_i h_{\tau-i},$$

where $p \geq 0$; $q \geq 0$; $\alpha_0 > 0$; $\alpha_i \geq 0$ for $i = 1, 2, \ldots, q$; and $\beta_i \geq 0$ for $i = 1, 2, \ldots, p$. With $p = 0$, equation (6) describes the ARCH(q) model. ARCH(1), ARCH(2), and GARCH(1,1) versions of equations (5) were estimated by maximum likelihood. (See Bollerslev for details.) The test of ARCH(2) versus ARCH(1) was significant at the 15% level.[7] As Bollerslev notes, the test statistics for tests of ARCH(2) and GARCH(1,1) versus an ARCH(1) null are equivalent. The test of ARCH(2) versus the null of homoscedastic errors ($\alpha_1 = \alpha_2 = 0$) was highly significant, indicating the importance of temporal variation in conditional variances for this series.[8] The ARCH(2) specification was preferred over the GARCH(1,1) specification because the former provided a slightly better fit. Table 1 presents the results of maximum likelihood estimation of equation (5) combined with the ARCH(2) version of equation (6). Ljung-Box statistics for tests of the autocorrelations of orders 1 through 12 of the residuals, $\hat{\zeta}_\tau$, and the standardized, squared residuals, $\hat{\zeta}_\tau^2/\hat{h}_\tau$ (McLeod and Li), are insignificant. Thus, the ARCH(2) model appears to describe adequately the serial dependence in the conditional forecast variances. Conditional forecast variances were estimated as $\hat{\alpha}_0 + \hat{\alpha}_1\hat{\zeta}_{\tau-1}^2 + \hat{\alpha}_2\hat{\zeta}_{\tau-2}^2$, where $\hat{\zeta}_{\tau-1}$ and $\hat{\zeta}_{\tau-2}$ are lagged residuals, for each week of the 1972–88 sample period. The weekly values of these expressions were averaged within each quarter to produce the measure of price uncertainty denoted by σ_{pt}^2 for t = 1972.I–1988.IV.

The Empirical Model

To identify separately η, ϵ, and the input and output market conjectural elasticities, the estimation procedure must combine the information contained in equation (4) with that of input supply and output demand relations, equations (1) and (2). Functional forms must be chosen for these relations as well as for several components of equation (4). Our first specification of the empirical model is

$$(7)\quad M_t = C_t - Q_t\eta_t^{-1}\theta_{1t} + Q_t\epsilon_t^{-1}\theta_{2t} + Q_t\delta\sigma_{pt}^2 + \nu_{1t}$$

$$(8)\quad Q_t = a_0 + a_1\frac{E[p_t]}{B_t} + a_2 D_{2t} + a_3 D_{3t} + a_4 D_{4t} + a_5 Z_t + a_6\frac{Y_t}{I_t} + \nu_{2t}$$

---

[7] The likelihood ratio statistic, distributed $\chi^2(1)$, equals 2.303.

[8] The likelihood ratio statistic, distributed $\chi^2(2)$, equals 27.526.

Table 1. Results of FIML Estimation of the ARCH(2) Specification of the Weekly Pork Price Forecasting Model [Equation (5)]

Parameter	Estimate	Standard Error
γ_0	2.5160	.5110
γ_1	1.0840	.0234
γ_2	−0.1815	.0442
γ_3	0.0862	.0429
γ_4	−0.0727	.0414
γ_5	0.1033	.0365
γ_6	−0.0591	.0164
γ_7	2.1750	.9735
γ_8	−1.8330	.8741
γ_9	0.6311	.3184
γ_{10}	−0.1075	.0570
γ_{11}	0.0089	.0050
γ_{12}	−0.0003	.0002
γ_{13}	−4.8410	1.049
γ_{14}	5.7240	1.110
γ_{15}	−2.3100	.4222
γ_{16}	0.3353	.0592
γ_{17}	−0.0025	.0004
α_0	3.6590	.2940
α_1	0.1265	.0387
α_2	0.0570	.0480

R^2 = .9707
Ljung-Box test statistics
($\chi^2(12)$) for:
$\hat{\zeta}_\tau$ 2.675
$\hat{\zeta}_\tau^2/\hat{h}_\tau$ 9.852

Note: Sample = 1972.13–1988.52.

$$(9)\quad \frac{Q_t}{S_t} = b_0 + b_1\frac{w_t}{\hat{w}_{t+1}} + b_2D_{2t} + b_3D_{3t} + b_4D_{4t} + b_5\frac{f_t}{\hat{w}_{t+1}} + b_6\frac{Q_{t-1}}{S_{t-1}} + b_7\frac{Q_{t-2}}{S_{t-2}} + b_8\frac{Q_{t-3}}{S_{t-3}} + b_9\frac{Q_{t-4}}{S_{t-4}} + \nu_{3t},$$

where

$$(10)\quad C_t = c_{1t}v_{1t} + c_{2t}v_{2t} + c_{3t}v_{3t} + c_{12t}(v_{1t}v_{2t})^{1/2};$$

$$(11)\quad c_{1t} = c_1 + c_{1x}X_t,\ c_{2t} = c_2 + c_{2x}X_t, \text{ and } c_{12t} = c_{12} + c_{12x}X_t;$$

$$(12)\quad \eta_t = \frac{a_1}{B_t};$$

$$(13)\quad \epsilon_t = \frac{b_1S_t}{\hat{w}_{t+1}};$$

$$(14)\quad \theta_{1t} = \theta_1;$$

$$(15)\quad \theta_{2t} = \theta_2; \text{ and}$$

$E[p_t]$ is wholesale pork price;
w_t is market hog price;
M_t is $E[p_t] - w_t$ is farm/wholesale pork margin;
Q_t is pork production;
v_{1t}, v_{2t}, and v_{3t} are prices of labor, energy, and transportation services;
σ^2_{pt} is conditional variance of one-week-ahead wholesale pork price forecast;
Z_t is population of the United States;
Y_t is nominal personal income;
I_t is consumer price index for food;
D_{2t}, D_{3t}, and D_{4t} are dummy variables for second, third, and fourth quarters;
B_t is wholesale beef price;
$\hat{w}_{t+1}$ is expected price of next quarter's hogs;
f_t is price of feed;
S_t is stock of "marketable" hogs;
X_t is average slaughter per plant; and
ν_{1t}, ν_{2t}, and ν_{3t} are random disturbance terms.

Equation (7) is simply equation (4) with time subscripts and an additive error term. Equations (8) and (9) are elaborations of equation (2) and (1), respectively. (Detailed definitions of variables are in the data appendix.) The theoretical model distinguishes the oligopoly and oligopsony distortion components of the margin from each other and from the remaining margin components by their relationships to demand and supply slopes. Identification of the market power terms therefore requires that the demand and supply functions display time-varying slopes. For demand, this is accomplished by introducing the price of pork, $E[p_t]$, through a ratio with B_t, the price of an important substitute, beef. The implied expression for the time-varying demand slope is given in equation (12). Other demand determinants include quarterly effects, population, and real income.

The supply of hogs is the solution to an intertemporal decision problem in which animals are both a consumption and an investment good (Myers and Havelicek). That is, hogs may be either marketed this period or retained for sale or to augment the breeding stock next period. Because the decision will turn on comparisons of current with expected future prices, our specification includes current hog and feed prices in ratios with a one-period-ahead forecast of next quarter's hog price.[9] In addition, current supply

[9] Values of $\hat{w}_{t+1}$ are the series of fitted values from a single-equation, reduced-form model for w_t. An Akaike Information Criterion search among sets of lagged prices, lagged quantities, and trend and seasonal terms led to the choice of a specification for the hog price-forecasting model.

is constrained, in part, by past marketings and breeding decisions. The dependent variable therefore is specified as this period's supply quantity as a proportion of marketable hogs, and lagged versions of this ratio enter the supply function as explanatory variables. The resulting expression for the time-varying supply slope is given by equation (13).

Theory also implies that the marginal processing cost function is linearly homogenous in factor prices. For simplicity, we take marginal cost to be independent of industry output and a generalized Leontief function of the prices of three factors: packing plant labor, energy, and transportation services; with substitution possibilities assumed between labor and energy only [equation (10)]. To accommodate the likelihood that the structure of marginal cost has changed with the industry's continuing movement toward larger plants, equations (11) express the cost function parameters pertinent to the labor and energy inputs as functions of average slaughter per plant, a proxy for average plant capacity. Finally, equations (14) and (15) fix the output and input market conduct parameters at constant values throughout the sample period.

Results

The empirical model, consisting of equations (7), (8), and (9), was estimated by full information maximum likelihood (FIML), subject to the functional forms and parameter restrictions of equations (10) through (15). Preliminary runs were conducted to investigate the possibility of serial correlation in the error terms. An AR(4) representation was estimated for each of the residual series from estimation of the model with no serial correlation correction. In the case of the supply equation residuals, none of the estimated autoregressive coefficients were significant. In the case of the margin and demand equation residual series, the first-order autoregressive coefficients were significant at the 1% level, while the second-, third-, and fourth-order coefficient estimates were not significant at the 5% level. Hence, our treatment assumed AR(1) disturbances for these two with coefficients denoted ρ_1 and ρ_2 for equations (7) and (8), respectively. The two equations were quasi-first-differenced, and the structural parameters were reestimated jointly with ρ_1 and ρ_2 by FIML.

When equations (10) through (15) are substituted into (7), the result is a margin decomposition that is notable in the conspicuous absence of a constant term. Again, this results from the fact that theory predicts that the oligopoly and oligopsony distortions are inversely proportional to demand and supply slopes, that the risk component is proportional to the conditional forecast variance, and that marginal cost is linearly homogenous in factor prices. Consequently, rejection of the hypothesis that a constant term in equation (7) is, in fact, zero is evidence against the model. Reestimating the model with a constant term added to (7), we found that the hypothesis that the term is zero could be rejected at the 2.5% level.[10]

Rejection of the model described by equations (7) through (15) could be caused by any of several features of the specification. One particularly restrictive aspect of this version, though, is that it constrains the conjectural variation terms to be constant values throughout the sample period. Therefore, this particular version is incapable of addressing one of the industry's most important policy questions: Has conduct changed with changing structure? To allow the conduct parameters to vary through time, we estimated the model with equations (14) and (15) replaced by (14′) and (15′):

$$(14') \qquad \theta_{1t} = \theta_{10} + \theta_{11}N_t$$

$$(15') \qquad \theta_{2t} = \theta_{20} + \theta_{21}X_t + \theta_{22}X_t^2,$$

where N_t, the national four-firm concentration ratio in hog packing in period t, is used as a proxy for structural change in the specification of the output market conjectural variation. Because hog markets are regional, we favor X_t, the average slaughter per plant, as an index of input market structure.[11]

Table 2 reports the results of FIML estimation of the revised model with AR(1) errors assumed for equations (7) and (8). This time, the hypothesis of no additional constant term in the margin equation is not rejected at conventional significance levels.[12] Demand and supply slopes are of the correct signs and highly significant. The demand effect of the population variable is positive and marginally significant, while that of real income is negative and insignificant. Significant quarterly effects appear in both demand and supply. The supply effect of the relative feed price variable, though insignificant,

[10] The likelihood ratio statistic, distributed $\chi^2(1)$, equals 5.464.

[11] When θ_{2t} was specified as a linear function of X_t, the estimates of θ_{2t} went significantly out of range (i.e., negative) over a portion of the sample period.

[12] The likelihood ratio statistic, distributed $\chi^2(1)$, equals 0.834.

Table 2. Results of FIML Estimation of Structural Model with Time-Varying Conjectural Variations [equations (7), (8), and (9) subject to (10) through (13), (14′), and (15′)]

Parameter	Estimate	Standard Error
c_1	−83.739	23.979
c_{1t}	59.525	16.669
c_2	−1.520	0.3886
c_{2t}	1.021	0.2652
c_{12}	23.046	6.0671
c_{12t}	−15.712	4.1912
c_3	0.007	0.0125
θ_{10}	−0.031	0.0424
θ_{11}	0.150	0.1300
θ_{20}	0.602	0.1765
θ_{21}	−0.618	0.2029
θ_{22}	0.157	0.0594
δ	0.000378	0.000145
a_0	3388.4	1325.4
a_1	−1509.9	165.56
a_2	−74.893	40.344
a_3	−115.480	43.142
a_4	278.970	39.935
a_5	11.091	7.3682
a_6	−73.671	65.618
b_0	−0.4580	0.1517
b_1	0.4638	0.0932
b_2	0.09934	0.0238
b_3	−0.0618	0.0229
b_4	0.0939	0.0242
b_5	0.4521	0.6859
b_6	0.7833	0.1631
b_7	−0.5796	0.1489
b_8	0.4490	0.1361
b_9	0.3000	0.1383
ρ_1	0.1525	0.1222
ρ_2	0.4866	0.1128

Log likelihood: −640.56

Squared simple correlations between actual values and one-period-ahead forecasts of

p .8655

w .9028

Q .9251

Note: Sample = 1972.II–1988.IV.

is positive as expected. The coefficients of the lagged supply quantity terms are all significant. Moreover, the implied difference equation in Q/S is dynamically stable at the point estimates.[13] Estimates of cost function parameters leave a bit to be desired, however. Monotonicity in the transportation service price is implied by the positive (though insignificant) estimate of c_3. Monotonicity in the wage and the energy price obtains at 87% and 63% of the sample points, respectively. Concavity of the cost function is satisfied at only 28% of the sample points.

Primary attention focuses on the significance of the market power and output price risk components of the spread equation. As will be seen presently, the implied oligopoly and oligopsony distortions are generally small and individually insignificant. Yet, the hypothesis that these distortions are both identically zero throughout the sample period ($\theta_{10} = \theta_{11} = \theta_{20} = \theta_{21} = \theta_{22} = 0$) can be rejected at the 0.5% level.[14] Furthermore the estimate of δ, the coefficient on the price risk term, is significantly positive at the 0.5% level. These findings attest to the importance of considering both market power and output price uncertainty effects in the analysis of marketing margins in this particular case.

Table 3 presents the implied margin decompositions for selected quarters. Throughout the sample period, the oligopoly component is relatively small and never achieves statistical significance at the 5% level (one-tailed test). This is not particularly surprising because the essentially national scope of hog packers' output market probably leaves firms little capability to exercise oligopoly power. The oligopsony distortions are significantly positive at the 5% level in seventeen of the sample's eighteen initial quarters (72.I through 76.II) and insignificant thereafter.[15] In spite of a trend toward heightened concentration in regional hog markets, input market power seems to be less of a problem in recent periods than in the early 1970s.[16] The output price risk components are uniformly significant at the 1% level (one-tailed test) and generally larger than either market power component.[17]

[13] This can be checked by appeal to the Schur theorem. See, for example, Chiang.

[14] The likelihood ratio statistic, distributed $\chi^2(5)$, equals 21.590.

[15] The negative estimates of the oligopsony distortion have no economic significance and are simply artifacts of the simple specification (15′) which does not constrain θ_{2t} to be nonnegative. None of these negative estimates even remotely approach significance. Our interpretation is that input market conduct was essentially competitive in these periods.

[16] Point estimates of oligopsony distortions trend upward over the sample's last six quarters. This trend is not ratified by statistical significance, however.

[17] The dearth of empirical research on agricultural price spreads in noncompetitive food industries in general, and pork price spreads in particular, makes a comparative assessment of our results difficult. Moreover, whatever literature exists on the subject varies widely in objectives, methodology, and data. Ward (1988), for example, using a model similar to that in Hall, Schmitz, and Cothern, regressed yearly pork margins (farm-to-carcass) on wage rates in meatpacking, commercial production, and four-firm concentration ratios in pork packing. His results showed that, between the years 1972 and 1985 (a sample period roughly comparable to ours), there was no significant impact of concentration on the farm-to-wholesale price spread in pork.

Table 3. Price Spread Decomposition for Selected Quarters

Quarter	Margin[a]	Oligopoly Component[b]	Oligopsony Component[c]	Output Price Risk Component[d]	Cost Component[e]
1972.III	23.070	1.982	4.571	4.601	11.916
		(1.514)	(2.457)	(1.773)	(3.579)
1973.IV	26.726	2.761	5.219	5.352	13.395
		(1.943)	(2.801)	(2.062)	(3.818)
1975.I	29.129	2.322	6.586	4.444	15.776
		(1.658)	(3.472)	(1.712)	(4.193)
1976.II	31.862	2.598	7.900	4.520	16.844
		(1.705)	(4.161)	(1.741)	(4.467)
1977.III	28.733	2.619	1.961	5.747	18.407
		(1.795)	(3.043)	(2.214)	(3.855)
1978.IV	31.288	3.924	1.278	5.471	20.616
		(2.689)	(3.235)	(2.108)	(4.091)
1980.I	30.848	5.751	-0.382	6.467	19.012
		(3.941)	(2.350)	(2.491)	(4.413)
1981.II	33.587	5.001	-0.339	6.276	22.649
		(3.626)	(3.562)	(2.418)	(4.917)
1982.III	32.931	4.450	-0.056	6.490	22.047
		(3.013)	(3.820)	(2.500)	(4.957)
1983.IV	31.682	4.551	-0.526	6.960	20.697
		(3.545)	(3.267)	(2.681)	(4.624)
1985.I	28.782	4.254	-1.316	5.675	20.169
		(3.136)	(3.246)	(2.186)	(4.616)
1986.II	25.664	3.803	0.211	6.795	14.855
		(2.758)	(6.106)	(2.618)	(6.255)
1987.III	28.182	5.214	0.693	7.180	15.095
		(3.291)	(5.107)	(2.766)	(6.659)
1988.IV	34.009	6.151	5.531	6.652	15.674
		(4.215)	(8.261)	(2.563)	(9.024)

Note: Dimensions for the margin and its components are ¢/wholesale pound. Standard errors (in parentheses) were computed using a first-order Taylor-series approximation about true parameter values and taking values of exogenous variables and quantity as fixed.

[a] These are fitted values of the margin, that is, sums of the three components for each quarter.

[b] Values of $-Q_t\hat{\eta}_t^{-1}(\hat{\theta}_{10} + \hat{\theta}_{11}N_t)$.

[c] Values of $Q_t\hat{\epsilon}_t^{-1}(\hat{\theta}_{20} + \hat{\theta}_{21}X_t + \hat{\theta}_{22}X_t^2)$.

[d] Values of $Q_t\hat{\delta}\sigma_{pt}^2$.

[e] Values of $(\hat{c}_1 + \hat{c}_{1x}X_t)v_{1t} + (\hat{c}_2 + \hat{c}_{2x}X_t)v_{2t} + (\hat{c}_{12} + \hat{c}_{12x}X_t)(v_{1t}v_{2t})^{1/2} + \hat{c}_3v_{3t}$.

The empirical results raise two important questions about the industry. Why the trend toward more competitive conduct at a time when an acceleration of mergers, acquisitions, and plant closings would lead one to expect more, not less, market power? What does the presence of a significant component resulting from output price risk suggest about the interpretation of margin behavior?

With respect to the first question, one plausible hypothesis which merits further investigation is that the larger average packing plant size of the 1980s produced incentives leading to a breakdown in the industry's oligopolistic discipline. A packer operating a large plant can achieve significant cost economies by assuring the necessary flow of inputs to operate the plant near capacity. The temptation to secure such cost savings may have overwhelmed the incentives for oligopolistic output restrictions.

The finding of a significant margin component resulting from price variability suggests decision makers' aversion to output price risk is important in margin determination in the industry. In this sense, our findings are consistent with those of BCGS for the milling industry, even though packers do not hold inventories as large or as long as millers. This cautions against analysis of margins without attention to the effects of output price uncertainty. For example, when the model was reestimated without the price risk term [by imposing $\delta = 0$ in equation (7)], the implied margin decompositions told a story somewhat different from that reported in table 3. Cost components were larger by 2¢ to 4¢ per pound, and oligopsony components were larger by less than 1.5¢ per pound while retaining essentially the same pattern of significance. Oligopoly components were larger by 1¢ to 3¢ per pound, however, and, more important, achieved

statistical significance at the 5% level (one-tailed test) at all sample points and at the 2.5% level at forty-six of the sixty-eight sample points. Ignoring the effects of price risk would have led, in this case, to an incorrect inference of output market power.

Concluding Comments

This paper develops a conceptual and empirical framework for analyzing marketing margins in a noncompetitive food industry facing output price uncertainty. The framework allows the decomposition of observed margins into four components: the marginal cost of the processing industry, oligopoly/oligopsony price distortions, and an output price risk component. Conjectural variations are used to parametrize the degree of market power in the industry and estimates of conditional forecast variances from an ARCH time-series model of price serve as a measure of output price risk.

The empirical model is implemented using data on farm/wholesale spreads for pork for the 1972.II to 1988.IV period. For this particular application, the farm/wholesale margins for pork were quite consistent with competitive performance in the 1980s but less so fifteen years ago. This result is mildly surprising in view of the fact that packer concentration in regional input markets has grown over the past decade to very high current levels. More important, we find that a significant output price risk component persisted throughout the sample and that ignoring this component in the empirical analysis would have led to an erroneous inference of noncompetitive conduct in the product market.

[Received August 1990; final revision received February 1991.]

References

Aradhyula, Satheesh V., and Matthew T. Holt. "Risk Behavior and Rational Expectations in the U.S. Broiler Market." *Amer. J. Agr. Econ.* 71(1989):892–902.

Azzam, Azzeddine, and Emilio Pagoulatos. "Testing Oligopolistic and Oligopsonistic Behaviour: An Application to the U.S. Meat-Packing Industry." *J. Agr. Econ.* 41(1990):362–70.

Azzam, Azzeddine, Emilio Pagoulatos, and John Schroeter. "Price Spreads and Market Power in Food Processing Industries." NEC-165 Work. Pap. No. 8, 1989.

Bollerslev, Tim. "Generalized Autoregressive Conditional Heteroskedasticity." *J. Econometrics* 31(1986):307–27.

Bresnahan, Timothy F. "Empirical Studies of Industries with Market Power." *Handbook of Industrial Organization*, vol. 2, ed. Richard Schmalensee and Robert Willig. New York: North-Holland Publishing Co., 1989.

Brorsen, B. W., J.-P. Chavas, W. Grant, and L. D. Schnake. "Marketing Margins and Price Uncertainty: The Case of the U.S. Wheat Market." *Amer. J. Agr. Econ.* 67(1985):521–28.

Chiang, Alpha C. *Fundamental Methods of Mathematical Economics*, 3rd ed. New York: McGraw-Hill Book Co., 1984.

Connor, J. M. "Concentration Issues in the U.S. Beef Subsector." *Competitive Issues in the Beef Sector: Can Beef Compete in the 1990's.* Minneapolis: Hubert Humphrey Institute of Public Affairs, University of Minnesota, 1989.

Engle, Robert F. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflations." *Econometrica* 50(1982):987–1007.

Gardner, B. L. "The Farm-Retail Price Spread." *Amer. J. Agr. Econ.* 57(1975):399–409.

Hall, Lana, A. Schmitz, and J. Cothern. "Beef Wholesale-Retail Marketing Margins and Concentration." *Economica* 46(1979):265–300.

Hayenga, Marvin, V. James Rhodes, Jon A. Brandt, and Ronald E. Deiter. *The U.S. Pork Sector: Changing Structure and Organization.* Ames: Iowa State University Press, 1985.

Judge, George G., William E. Griffiths, R. Carter Hill, and Tsoung-Chao Lee. *The Theory and Practice of Econometrics.* New York: John Wiley & Sons, 1980.

Just, R., and W. Chern. "Tomatoes, Technology, and Oligopsony." *Bell J. Econ.* 11(1980):584–602.

Leland, Hayne E. "Theory of the Firm Facing Uncertain Demand." *Amer. Econ. Rev.* 62(1972):278–91.

Ljung, Greta M., and George E. P. Box. "On a Measure of Lack of Fit in Time Series Models." *Biometrika* 65(1978):297–303.

Lopez, R. E. "Measuring Oligopoly Power and Production Responses of the Canadian Food Processing Industry." *J. Agr. Econ.* 35(1984):219–30.

McLeod, A. J., and W. K. Li. "Diagnostic Checking of ARMA Time Series Models Using Squared-Residual Autocorrelations." *J. Time Series Anal.* 4(1983):269–73.

Myers, Lester H., and Joseph Havelicek, Jr. "Some Theoretical Aspects of Short-Term Hog Supply." *J. Farm Econ.* 49(1967):1395–1400.

Nelson, Kenneth E. "Issues and Developments in the U.S. Meatpacking Industry." Washington DC: U.S. Department of Agriculture, ERS Staff Rep. No. AGES 850502, 1985.

Sandmo, A. "On the Theory of the Competitive Firm Under Price Uncertainty." *Amer. Econ. Rev.* 61(1971):65–73.

Schroeter, John R. "Estimating the Degree of Market Power in the Beef Packing Industry." *Rev. Econ. and Statist.* 70(1988):158–62.

Schroeter, John R., and Azzeddine Azzam. "Measuring Market Power in Multi-Product Oligopolies: The U.S. Meat Industry." *Appl. Econ.* 22(1990):1365–76.

U.S. Department of Agriculture, Economic Research Service. *Agr. Outlook*. Washington DC, various issues.
——. *Livestock and Meat Statist*. Washington DC, various issues.
——. *Livestock and Poultry Situation and Outlook Rep*. Washington DC, various issues.
U.S. Department of Commerce, Bureau of the Census. *Current Population Reports—Population Estimates and Projections*. Washington DC, various issues.
U.S. Department of Energy, Energy Information Administration. *Monthly Energy Rev*. Washington DC, various issues.
U.S. Department of Labor, Bureau of Labor Statistics. *Employment and Earnings*. Washington DC, various issues.
Ward Clement E. *Meatpacking Competition and Pricing*. Blacksburg VA: Research Institute on Livestock Pricing, 1988.
——. "Structural Change: Implications for Competition and Pricing in the Feeder-Packer Subsector." *Structural Change in Livestock: Causes, Implications, Alternatives*, ed. Wayne Purcell. Blacksburg VA: Research Institute on Livestock Pricing, 1990.

Appendix

Data

Except where noted, data on the model's variables were collected from U.S. government publications, *Livestock and Poultry Situation, Livestock and Meat Statistics, Employment and Earnings, Economic Report of the President, Agricultural Outlook, Current Population Reports, and Monthly Energy Review*.

Q_t Commercial pork production in the United States (million lbs., carcass weight)

Z_t U.S. population (millions)

p_t Pork wholesale value. (¢/wholesale lb.)

I_t Consumer price index, food items (1967 = 100)

P_τ Carcass-proportion-weighted average of weekly averages of daily closing quotations of prices of hams, bellies, loins, and spareribs (¢/wholesale lb.) (Data provided by the National Provisioners.)

Y_t Nominal disposable personal income ($ billion, annual rate)

w_t Pork net farm value = market value to the producer of 1.6038 lbs. live hog (equivalent to 1 lb. wholesale) minus by-product allowance (¢/wholesale lb.)

B_t Beef wholesale value minus carcass by-product allowance (¢/wholesale lb.)

f_t Wholesale price of No. 2 yellow corn ($/bu.)

S_t Quarterly pig crop 6 months prior to date t (million lbs., projected carcass weight at marketing)

v_{1t} Production worker average hourly earning in SIC 2011 (meat packing plants) ($/hour)

v_{2t} Price index for fuels and related products and power (1967 = 100)

v_{3t} Price index of No. 2 diesel fuel to commercial customers (1973 = 100)

X_t Average U.S. hog slaughter per plant (quarterly figures interpolated from yearly totals) (Data provided by Clement Ward.)

N_t U.S. four-firm concentration ratio in hog packing (quarterly figures interpolated from yearly totals) (Source: Connor.)

The Creation of Dominant Firm Market Power in the Coconut Oil Export Market

David E. Buschena and Jeffrey M. Perloff

Econometric results show that prior to the 1970s the Philippine coconut oil export market was competitive but that legal and institutional changes in the early 1970s, which centralized control of the Philippine coconut oil-refining and exporting industries, allowed the Philippines to exercise some of its potential dominant firm market power.

Key words: dominant firm, coconut oil, international trade, market power.

The Philippines, which supplies four-fifths of the world's coconut oil exports, made several fundamental legal and institutional changes to its export industry in the early 1970s that may have created dominant firm market power. A model is estimated that allows us to determine whether these changes allowed the Philippines to be a dominant firm, exercise limited market power, or remain a price taker. In the model, the degree of market power exercised by the (possibly) dominant firm is estimated as a function of the institutional and legal changes.[1]

In the next section, the world export market for coconut oil is described. The derivation of the model is presented in the second section. In the third section, the data sources are listed. The model is applied to the coconut oil export market in the next section. The estimated model is used to determine the magnitude of the wedge between price and marginal cost in the fifth section. The summary and conclusions are presented in the final section.

The Coconut Oil Export Market

Several important institutional, legal, and economic changes affected the potential market power of the Philippines in the coconut oil export market. We first consider those factors that tend to increase Philippine market power and then those that tend to decrease it.

The Philippines has been and is by far the largest producer and exporter of coconut oil. From 1978 to 1987, the Philippine share of world coconut oil exports averaged 79%. Two factors apparently allowed the Philippines to exercise more dominant firm market power in recent years. First, in the 1970s, the Philippine export industry changed from atomistic to highly concentrated. Second, over time, other nations reduced their capacity to export coconut oil.

The Philippine coconut oil refining and export industries became more concentrated following the imposition of a tax on the first copra (dried coconut meat or kernel from which coconut oil and copra cake or meal are extracted) sales and the creation of a centralized agency (Hawes).[2] Before then, a large number of domestic and foreign-owned firms refined and exported coconut oil, with foreign firms accounting for the largest share of coconut oil exports. In 1971, a levy on the first domestic sale of copra was es-

---

David E. Buschena and Jeffrey M. Perloff are, respectively, a graduate student and a professor, Department of Agricultural and Resource Economics, University of California, Berkeley.

Giannini Foundation Paper No. 1001 (for reprint request identification only).

The authors are grateful to Peter Berck, James Chalfant, George Judge, Scott Templeton, and the anonymous referees for useful comments.

[1]For a theoretical presentation of the standard dominant firm-competitive fringe model, see Carlton and Perloff. Our model generalizes the monopoly/monopsony models of Just and Chern, Bresnahan, and Lau by allowing for a dominant firm-competitive fringe market structure and for the parameter measuring market power to vary with institutional and legal changes. We use a residual demand (market demand net of the competitive supply of other firms) approach analogous to the models of Baker and Bresnahan, Spiller and Favaro, and Karp and Perloff (1989b), which do not allow market power to vary as in our model.

[2]Both coconut oil and copra are exported. In the following, copra exports are converted to their coconut oil equivalents because coconut oil is a virtually fixed proportion of copra: On average 64% of copra by weight is coconut oil, and the standard deviation from year to year is only 0.3%. Copra cake, which is a by-product of the oil extraction process, is fed to livestock. Most of the Philippine copra cake is used in the Philippines or exported to Europe. The cake is not discussed further in this paper.

tablished. The proceeds from this levy went to finance production loans and industrial investments and to support the Philippine Coconut Producers Federation (COCOFED). The revenues from this levy were used by COCOFED to finance its activities toward gaining market power.

At the urging of COCOFED and others, the Philippine Coconut Authority (PCA) was created in June 1973 by presidential decree (Hawes). The PCA was a centralized agency that eventually gained control of the levies on coconut sales, seed research funding, investment in new mills and the purchase of existing mills, subsidies for refining and export, and floor and ceiling price setting. By 1974, the PCA was controlled by COCOFED (3 members), another coconut planters' organization (1 member), Philippine National Bank officials (2 members), and a hybrid coconut seednut farm (1 member).

By 1980, the PCA controlled 80% of the Philippine refining capacity through its subsidiary United Coconut Oil Mills (UNICOM) and dominated the coconut oil export market. This control was achieved by purchases financed through funds from the levies on coconut sales and arranged through the PCA's United Coconut Planters Bank. In short, the Philippine coconut-refining and export industry changed from one of relatively strong export competition to a highly concentrated industry within about six years.

Over time, the exports of the Philippines' five major competitors in the export of coconut oil (Malaysia, Indonesia, Sri Lanka, Papua New Guinea, and the Ivory Coast) fell. Coconut acreage in Malaysia and Indonesia, two of the largest of these fringe coconut oil exporters, decreased primarily because of government-supported efforts to increase oil palm acreage. Oil palm trees reach maturity faster than coconut palm trees and are better suited to the climatic conditions in Malaysia and Indonesia. Indonesia was the second largest coconut oil exporter in the 1950s and 1960s, but a 1968 revolution and the subsequent period of instability (Bunge 1984a) caused many existing coconut plantations to be neglected, permanently reducing tree-life span and hastening the replacement of coconut acreage by oil palm. Malaysia also suffered serious racial unrest beginning in 1969; its parliamentary government was consequently suspended until 1971 as a result of this unrest (Bunge 1984b).

Offsetting these changes that were favorable to the Philippines were three other factors that tended to lower the demand for coconut oil or increase the elasticity of demand. First, the technological ability to substitute other oils for coconut oil in various uses has increased over time. Coconut oil has both food (shortening, salad and cooking oils, margarine, and baked goods) and nonfood (soap, paint and varnish, fatty acids, resins and plastics, and lubricants) uses.[3] The tropical oils that are high in saturated fats (coconut, palm, and palm kernel) differ in taste, melting temperatures, and flash points from other oils. Over time, soybean, cottonseed, and other oils have become closer substitutes for the tropical oils in foods through advancements in oil-processing technology. For example, oils that are low in saturated fats now can be hydrogenated to give them some of the physical characteristics of coconut and palm oil. Coconut and palm oils, however, still possess certain chemical properties that make them the oils of choice for some nonedible and processed food products. This lack of perfect substitutability between oils is shown by the cross-price elasticities between coconut oil and other oils: .44 with palm oil, .18 (not statistically significantly different from zero at the 0.05 level) with soybean oil, .09 with cottonseed oil, and .03 with peanut oil. Nonetheless, coconut oil's share of world edible oil exports has fallen over time: In 1961–63, coconut oil was 15% of total world edible oil exports; in 1971–73, it was 10%; and in 1981–83, it was 7%.

Second, consumers have become increasingly concerned about the amount and types of fat in their diets. In 1961, the American Medical Association (AMA) announced guidelines for total and saturated fat in the diet. In the late 1970s, various groups (Rizek et al.) made stronger recommendations to reduce the intake of saturated fat, including the U.S. Senate Select Committee on Nutrition and Human Needs in 1977, the American Heart Association in 1978, the U.S. Surgeon General in 1979, the AMA in 1979, and the U.S. Departments of Agriculture and Health, Education, and Welfare in 1980. Until recently, however, most consumers probably did not realize that the tropical oils—coconut, palm, and palm kernel—were high in saturated fats.[4]

---

[3]In the United States, relatively small amounts of coconut oil imports are used in foods (27% in 1962 and 33% in 1986), whereas 75% and 67% of coconut oil imports of the United Kingdom and the Netherlands, respectively, were used in foods in 1962 (Woodroof).

[4]Coconut oil is higher in saturated fats, which are believed to be particularly harmful, than are most other dietary fats and oils. The percentage of saturated fats are: coconut oil, 77–92; butterfat, 54–66; palm oil, 51; beef fat, 51; animal fat shortening (precreamed), 44; lard, 41; chicken fat, 30; cottonseed oil, 27; margarine (fat), 18; soybean oil, 15; olive oil, 14%; peanut or corn oils, 13; sunflower oil, 11; safflower oil 9; and canola, 6.

In 1989, pressure by health groups and Phil Sokolof (who, in the fall of 1988, paid for full-page advertisements in national newspapers criticizing manufacturers for using tropical oils) caused several major food processors to promise to substitute unsaturated vegetable fats for saturated tropical fats in their products (*Time*). Europeans are also becoming more concerned with the health implications of saturated fats. These health concerns eventually should reduce the demand for coconut oil in foods over time, though such a drop in demand may not be apparent for a few more years.

Third, the United States, which, 1959–87, imported 40% of the world's total shipment of coconut oil, gave the Philippines a waiver of the 3¢ per pound tariff on coconut oil imports (up to a quota limit) from 1921 to 1974. As a result, the Philippines provided virtually all the coconut oil in the United States (Hawes, p. 60). After 1974, a 1¢ per pound tariff was applied to Philippine coconut oil imports, while the tariff on coconut oil imports from other nations was gradually reduced to a level equal that of the Philippines. Given the ten-year lags until bearing age and the sixty-year life of coconut palms (Woodroof, p. 38), the historical tariff differential is probably still having a substantial effect today. This effect should diminish over time.[5] Before 1974, virtually all U.S. imports were from the Philippines, whereas from 1977 to 1986 the Philippines accounted for only 82% of U.S. imports, even though its share of total world exports has risen over time.

The Model

A dominant firm and competitive fringe model is used to describe the world coconut oil export market. The model allows for competitive, dominant firm, and intermediate types of behavior by the Philippines. A three-equation system is estimated: world demand, competitive fringe supply, and the Philippine export equation.

The world's market demand curve is

$$Q = Q(p, Z), \tag{1}$$

where Q represents world purchase, p is the real price of this homogenous product, and Z is a vector of other variables that affect demand. The competitive (price-taking) supply, Q_f, of the fringe is

$$Q_f = Q_f(p, X), \tag{2}$$

where X is a vector of other variables that affect the quantity exported.

The residual demand facing the dominant firm is the world demand minus the competitive fringe's supply:

$$Q_d(p, Z, X) = Q(p, Z) - Q_f(p, X). \tag{3}$$

The dominant firm maximizes its profits subject to its residual demand. If the dominant firm fully exercises its market power, its equilibrium condition is determined by equating its marginal revenue (corresponding to its residual demand curve) and its marginal cost, MC.

To the degree that political, domestic market, and other considerations affect the decision making by Philippine authorities, the Philippine exports may deviate from the profit-maximizing level. Rather than try to model the objective function explicitly, we try to measure only the degree of market power (defined as the markup of price over marginal cost) actually exercised. Thus, instead of assuming profit maximization, where marginal revenue equals marginal cost condition, we write the Philippine export equation as

$$p(Q_d, Z, X) + \lambda p'(Q_d, Z, X)Q_d = MC, \text{ or}$$

$$p(Q_d, Z, X) = MC - \lambda p'(Q_d, Z, X)Q_d, \tag{4}$$

where $p(Q_d, Z, X)$ is the inverted residual demand curve [equation (3) solved for p as a function of Q_d], $p'(Q_d, Z, X)$ is the first derivative of the residual demand curve with respect to Q_d, and $p(Q_d, Z, X) + \lambda p'(Q_d, Z, X)Q_d$ is its effective marginal revenue taking into account political and other tradeoffs within the decision-making body. That is, λ, which determines the gap between price and marginal cost, reflects the degree of market power actually exercised. If λ is 0, the Philippines behaves competitively; if λ is 1, it uses all its potential market power with respect to its residual demand curve (standard dominant firm model); and if λ lies between 0 and 1, it exercises an intermediate level of market power.

Whether λ is identified depends on the functional forms. For example, λ is not identified in strictly linear or log-linear specifications. Just and Chern, Bresnahan, and Lau show that, for

[5] In addition to the results discussed below, we estimated a system of equations that included a 1974 dummy variable affecting marginal cost to account for the change in U.S. tariff policy toward Philippine coconut oil imports. Because the coefficient on this dummy was small and statistically insignificant, the system of equations reported below does not include this variable.

a monopoly or monopsony, a sufficient condition for the identification of λ is that the relevant demand curve is not separable in all variables, X and Z. Because the relevant demand curve here is the residual demand curve, any X or Z variable that rotates the market demand curve in price-output space without affecting the MC curve is sufficient to identify λ. Similarly, λ is identified if either the fringe supply curve alone rotates or both the fringe supply and demand curves rotate. That is, there are more sufficient conditions for identification in our dominant firm model than in the standard monopoly model.

To estimate this system of three equations, (1), (2), and (4), we use explicit functional forms. The world demand and fringe supply curves are assumed to be linear in coefficients but to contain interactive terms—the products of pairs of variables—that allow for the rotation necessary to identify λ.

The estimated world-wide demand equation (1) is

$$(1') \quad Q = \alpha_0 + \alpha_1 p + \alpha_2 Z + \alpha_3 p Z_1 + \epsilon_1,$$

where Z is a vector of exogenous factors that affect demand, Z_1 is a subset of these factors that enter the equation as cross products with the price, and ϵ_1 is a normal error term capturing random fluctuations in demand. The sources of the variables are listed in the next section, and table 1 presents the means and standard deviations. The Z variables include the real prices of palm oil (the other major tropical oil), soybean oil, cottonseed oil, and peanut oil; real income measures in consuming nations (Gross National Product, GNP, in the United States and European Community, EC);[6] the number of articles listed in the *Reader's Guide to Periodical Literature* on fats in the diet (a proxy for public concern about saturated fats);[7] and two time trends (other proxies for shifts in demand due to avoidance of saturated fats and the increased technical ability to substitute other oils in final products not captured by other Z variables). The time trend was split into two periods 1959–76 and 1977–87 (each starting at one and increasing by one each year) to capture changes in demand due to a large increase, starting in about 1977, in the number and severity of warnings concerning saturated fat intake by health groups. The Z_1 variables are the same two time trends. The real price of coconut oil, p, is an average of monthly coconut oil prices on the U.S. Pacific coast.[8]

[6] Only nine countries are included in our EC figures. Spain, Portugal, and Greece, which did not join the EC until relatively late in our sample period, are not included.

[7] A similar index was used in Brown and Schrader.

[8] We did not use a Philippine export price series because none is systematically reported. By dividing the value of coconut oil exports index by the quantity index reported by the *Philippine Statistical Yearbook*, however, one can calculate a Philippine coconut export price index. The correlation between that index and the U.S. price is .99. The comparable correlation of the U.S. price with the European price is .96. Thus, although we use the U.S. price series, which is reported in levels rather than as an index, using the Philippine index would give the same results.

Table 1. Means and Standard Deviations, 1959–87 Annual Data

	Mean	Standard Deviation
Endogenous variables		
Real price of coconut oil (¢/lb)	45.35	18.45
Quantity, Philippines (1,000 metric tons)	874.72	251.22
Quantity of the fringe (1,000 metric tons)	314.09	111.51
Exogenous variables		
Real price of palm oil (¢/lb)	31.25	11.16
Real price of soybean oil (¢/lb)	25.43	8.81
Real price of cottonseed oil (¢/lb)	44.17	16.01
Real price of peanut oil (¢/lb)	54.39	18.43
Real U.S. Gross National Product ($ trillion)	1.77	.12
Real EC Gross National Product ($ trillion)[a]	.79	.60
Fringe population (in millions)[b]	152.79	28.64
Real fringe Gross National Product ($ billions)[b]	10.35	3.64
Number of magazine articles on the risk from fats	1.83	3.90
Philippines farm wage index (real)	50.13	42.46
Minimum rainfall (millimeters)	20.20	12.90
Real freight rate ($/metric ton)	13.55	5.07

Source: See the text.
[a] Does not include Spain, Portugal, and Greece, which joined the EC relatively late in our sample period.
[b] Includes Indonesia, Malaysia, and Sri Lanka.

The estimated fringe export supply equation (2) is

$$(2') \qquad Q_f = \beta_0 + \beta_1 p + \beta_2 X + \epsilon_2,$$

where X is a vector of exogenous variables: a dummy variable reflecting the decreased capacity due to the Indonesian revolution and Malaysian unrest (1 from 1969 on); a dummy variable indicating a return to normalcy in Malaysia (1 from 1972 on); a time trend (starting at 1 in 1959); population and GNP for Malaysia, Indonesia, and Sri Lanka (to capture domestic demand effects); the time trend squared; the time trend cubed, the freight rate; and ϵ_2 is a normal error term reflecting random fluctuations in fringe supply. The time trends are proxies for unavailable cost and weather measures.

The residual demand facing the Philippines is the difference between (1′) and (2′):

$$\begin{aligned} Q_d \equiv Q - Q_f = (\alpha_0 - \beta_0) \\ + (\alpha_1 - \beta_1 + \alpha_3 Z_1)p \\ + \alpha_2 Z - \beta_2 X + (\epsilon_1 - \epsilon_2) \text{ or} \end{aligned}$$

$$(3') \qquad \begin{aligned} Q_d = \delta_0 + (\delta_1 + \delta_2 Z_1)p + \delta_3 Z \\ + \delta_4 X + (\epsilon_1 - \epsilon_2), \end{aligned}$$

where the slope of the residual demand curve, $\partial Q_d/\partial p = \delta_1 + \delta_2 Z_1$, is negative. The Philippine marginal cost of producing and exporting coconut oil is

$$(5) \qquad MC = \theta_0 + \theta_1 Q_d + \theta_2 W,$$

where W is a vector of exogenous variables that affect the marginal costs of producing and exporting coconut oil. Included in W are a real plantation wage index for the Philippines, the minimum monthly average rainfall for two reporting locations near Philippine coconut production areas (Davao City and Iloilo), a one-period lag of the minimum rainfall variable, and a real ocean freight rate index for grain from the mouth of the St. Lawrence River to Antwerp/Rotterdam (the most appropriate, bulk agricultural commodity shipping rate available for the entire period). A lack of steady rain lowers coconut production in the following period. Current minimum rainfall also was included to capture immediate effects on production, though the justification for including it is weaker than for the lagged value. A dummy variable for 1986 (one in 1986, zero otherwise) is included to capture increases in the marginal cost resulting from unrest during the transfer of power from President Marcos to President Aquino.[9]

Using (5) and (3′), the dominant exporting firm's first-order condition for profit maximization (4) can be rewritten as

(4′)

$$p = \theta_0 + \theta_1 Q_d + \theta_2 W - \frac{\lambda}{\delta_1 + \delta_2 Z_1} Q_d + \epsilon_3,$$

where ϵ_3 reflects random fluctuations in marginal cost or in maximizing behavior.[10] Using the estimates of δ_1 and δ_2 from equations (1′) and (2′), λ is identified in equation (4′).

Because the legal and institutional changes in the Philippines may have affected its market power in the coconut oil market, our model allows the market power parameter, λ, to vary with these changes. In particular, we focus on the effects of the levy, which was first collected in 1971, and the creation of the PCA in 1973. That is,

$$(6) \qquad \lambda = \lambda_0 + \lambda_1 D_{1972} + \lambda_2 D_{1974},$$

where D_{1972} and D_{1974} are dummy variables that take on the value 1 from 1972 (the first full season after the levy was instituted) on and from 1974 (the first full season after the PCA was established) on, respectively. Thus, λ_0 is the measure of the degree to which potential market power was exercised prior to 1972, $\lambda_0 + \lambda_1$ is the measure for 1972–73, and $\lambda_0 + \lambda_1 + \lambda_2$ is the measure for 1974 on.

The Data

The means and standard deviations of the variables used in this study are shown in table 1. The price of coconut oil is an unweighted average of monthly coconut oil prices at the U.S. Pacific coast from the *CRB Commodity Yearbook,* deflated by the U.S. GNP deflator. The

[9] From 1970 on, there was substantial political unrest in the Philippines, and martial law was in effect from 1972 to 1981. We concentrate on the 1986 transition period because it was apparently more significant than the earlier unrest and this period is clearly delineated.

[10] Our model treats the exporting problem as a static problem where large inventory holdings are impractical and we do not have to solve simultaneously the problem of how much coconut oil to reserve for domestic use. An attempt to estimate a dynamic model analogous to Karp and Perloff (1989a) was unsuccessful. Because coconut palms do not bear until they are 10 years old and have a 50- to 60-year bearing life, treating planting decisions as predetermined is reasonable. Including Philippine population and income measures in the Philippine export equation has little qualitative effect, and neither measure is statistically significant.

U.S. price is highly correlated with the European price. Prices for substitute oils (palm, soybean, cottonseed, and peanut) were calculated in the same manner and are from the *CRB Commodity Yearbook.*

The exports and imports of coconut oil reported by nation and the palm oil price at the Port of Rotterdam are from *Fruit and Tropical Products*. Because this source provides data only through 1987, our estimates cover only through 1987.

The freight rates for grain from the mouth of the St. Lawrence River to Rotterdam are listed in *Commodity Trade and Price Trends*. The minimum monthly rainfall data are listed in the *Philippine Statistical Yearbook*. Rainfall levels for 1987 were not available; the mean minimum rainfall value for 1959–87 was used for 1987.

The Philippine farm wage index was constructed from two sources: *Yearbook of Labour Statistics*, manufacturing wage index, 1959–81, and the *Philippine Statistical Yearbook's* legislated money wage for nonplantation agriculture, 1972–87. A regression of the wage index on the legislated money wage was used to create a continuous wage measure for the entire period. The correlation coefficient between these two wage sources is 0.88.

All of the data on population and national income (GNP) for the United States, EC, and for Indonesia, Malaysia, and Sri Lanka are from *International Financial Statistics*. The number of published magazine articles concerning fat in the diet is a count of listings under key headings in the *Reader's Guide to Periodic Literature*.

Estimation

Did the concentration of control of processing and exports of the Philippines lead to market power in the sense that prices are above marginal cost? To answer this question, we estimated our model using nonlinear three-stage least squares (NL3S) based on annual data for 1959–87. The parameter estimates and their standard errors are given in table 2.

Demand Equation

Based on an asymptotic *t*-test, we can reject the hypothesis that the coefficient on the price variable is zero at the 0.05 level. The price-time trend interactions indicate that the demand curve rotated each successive year, at least from 1977 on, when warnings about saturated fats became intense and technological advance increased substitutability with other oils. The rotation is illustrated in figure 1 where "Demand Curve 1980" is the actual demand curve in 1980 and "Demand Curve 1982" shows how the demand curve would have shifted over the next two years because of changes in the time trends terms and price-time trend interaction terms only (that is, other variables are held at their 1980 levels). A Wald test of the joint hypothesis that the coefficients of the price term and the two time-price interaction terms were collectively zero is rejected at the 0.05 significance level. That is, the demand curve statistically significantly slopes downward taking into account the interaction terms.

The coefficients of the real prices of substitute vegetable oils have the expected signs. Of the oil prices, only the tropical oil (palm oil) was significantly different from zero at the 0.05 level. Because of the multicollinearity of the prices of the nontropical oils (soybean, cottonseed, and peanut), it is not surprising that they are not statistically significant individually. Similarly, a joint Wald test against the hypothesis that the coefficients of the nontropical oils are collectively zero is not rejected at the 0.05 level. The average cross-elasticities (the change in the quantity of coconut oil exported as the price of another oil increases) for the entire period are .44 for palm oil, .18 for soybean oil, .09 for cottonseed oil, and .03 for peanut oil.

The number of magazine articles on the health dangers of saturated fats did not have a statistically significant effect, although, presumably, the time trend terms captured this effect. The income coefficients are not statistically significantly different from zero at the 0.05 level.

The correlation between predicted and actual values is 0.57. The Durbin-Watson statistic does not indicate significant autocorrelation for the demand equation.

Fringe Export Supply Equation

The slope of the fringe supply curve is not statistically significantly different from vertical, although there are distinct trends in fringe exports over time. This result is not surprising if one looks at the data: exports of some of the fringe countries hardly changed from year to year (except during periods of political unrest) despite large changes in the real price of coconut oil. In other countries, exports fell as the real price rose

Table 2. Iterative Nonlinear Simultaneous Equation System Estimates, 1959–87 Annual Data

	Coefficient	Asymptotic Standard Error	p–Value
Demand Equation (World Coconut Oil Exports)			
Intercept	424.060	381.170	.141
Real coconut oil price	−9.451	3.744	.011
Real palm oil price	16.224	5.745	.006
Real soybean oil price	7.872	5.843	.098
Real peanut oil price	.563	4.538	.451
Real cottonseed oil price	2.223	7.751	.389
Real U.S. GNP ($ trillions)	.145	.122	.125
Real EC GNP ($ trillions)	.186	.134	.091
Real price × time trend (1959–76)	−.170	.119	.086
Real price × time trend (1977–87)	−2.137	.756	.006
Time trend for 1959–76	12.340	9.869	.114
Time trend for 1977–87	30.725	45.649	.255
Magazine articles	4.647	18.179	.401
Correlation between predicted and actual values = .57			
D-W = 2.29			
Fringe Supply Equation (Fringe Exports)			
Intercept	1669.500	899.100	.037
Real coconut oil price	−.445	.620	.241
Time trend (1959–87)	78.655	37.446	.024
Time trend squared	−5.300	1.663	.002
Time trend cubed	.132	.038	.001
Real fringe GNP ($ millions)	.022	.014	.066
Fringe population (millions)	−13.775	9.141	.074
1969 dummy (1969–87 = 1)	−123.380	46.526	.001
1971 dummy (1971–87 = 1)	147.470	45.089	.002
Freight rate	−.577	2.240	.408
Correlation between predicted and actual values = .85			
D-W = 1.80			
Philippine Export Equation (Price of Coconut Exports)			
Intercept	86.486	16.871	.000
Quantity	−.085	.021	.000
Farm wage	−.019	.077	.406
Minimum rainfall	.001	.157	.498
Lagged min. rainfall	−.299	.140	.023
Freight rate	.891	.446	.030
1986 dummy (1986 = 1)	18.135	11.116	.059
λ_0	.314	.247	.109
λ_1	−.079	.104	.228
λ_2	.343	.127	.007
Correlation between predicted and actual values = .75			
D-W = 1.60			

because of government policies to induce growers to replace coconut trees with palm trees. Parameter estimates on the political dummy variables show that the 1969 unrest in Indonesia and Malaysia caused a large, statistically significant reduction in exports; however, supply increased statistically significantly with the return to normalcy in Malaysia in 1971.

The freight rate does not have a statistically significant effect. Coconut oil exports increase with fringe GNP and decrease with fringe population, as we would expect, but these effects are only marginally statistically significant. The correlation between predicted and actual exports is 0.85 and the Durbin-Watson statistic is 1.8.

Philippine Export Equation

Based on the estimates of the Philippine export equation (4′), the Philippine marginal cost de-

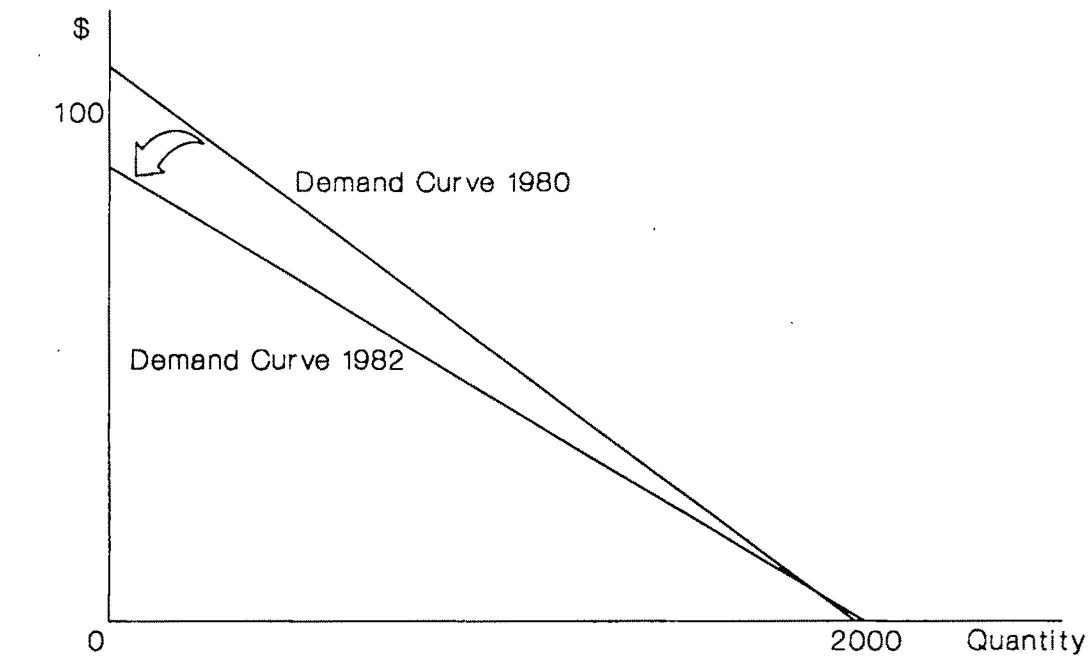


Figure 1. Shift of demand curve over time

creases statistically significantly with quantity exported, decreases with higher lagged minimum rainfall, and increases with higher levels of the freight rate. The wage and minimum rainfall coefficients were not precisely measured. Apparently, price increased as a result of the 1986 political unrest. The correlation between predicted and actual values is 0.75. The Durbin-Watson statistic is 1.6.[11] The second-order condition for the Philippine export equation is statistically significantly negative in each year of the sample.

Based on an asymptotic t-test, we cannot reject the hypothesis that the Philippines acted as a price taker ($\lambda = 0$) prior to the imposition of the levy in 1971. The institutional changes ($\hat{\lambda}_1 = -.079$) at the time of the levy do not have a statistically significant effect. The changes after 1973 (following the creation of the PCA), however, had a large, statistically significant effect ($\hat{\lambda}_2 = 0.34$). The 95% confidence interval on λ_2 is (0.29, 0.39). Our estimate of Philippine market power from 1974 on is $\hat{\lambda}_0 + \hat{\lambda}_1 + \hat{\lambda}_2 = .578$, with an asymptotic t-test against price taking ($\lambda_0 + \lambda_1 + \lambda_2 = 0$) of 1.94 and against traditional dominant firm behavior ($\lambda_0 + \lambda_1 + \lambda_2 = 1$) of 1.41. Reestimating this system of equations assuming price-taking behavior through 1973 (setting $\lambda_0 = \lambda_1 = 0$), the estimate of $\hat{\lambda}_2$ is .278 (asymptotic standard error = .108), with an asymptotic t-statistic against price taking of 2.57 and against traditional dominant firm behavior of 6.69, so both hypotheses are rejected at the 0.05 level.

[11] Reestimating the system to allow for first-order autocorrelation resulted in estimated correlation coefficients that did not differ statistically significantly from zero, and the qualitative results of the model are unchanged. As a result, we report the unadjusted estimates.

Market Power

How large a wedge between price and marginal cost does the estimated level of market power imply after 1974? As shown in equation (4), the wedge is $p - MC = -\lambda p'(Q_d, Z, X)Q_d$. One useful normalization of the wedge is Lerner's measure, $(p - MC)/p = \lambda/\epsilon$, where $\epsilon = -(dQ_d/dp)/(p/Q_d)$ is the absolute value of the residual demand elasticity. Lerner's measure is zero by definition under perfect competition ($\lambda = 0$). The estimated Lerner's measure was .61 at the mean of the entire sample period, .41 for the mean of the pre-PCA period (1959–73), and .89 for mean of the post-PCA period. The corresponding effective elasticities (ϵ/λ) for the same three periods are -1.64, -2.44, and -1.12.

Another way of thinking about the amount of market power exhibited by the Philippines is to

calculate how many identical Cournot firms the PCA would have had to create to obtain the market power observed. With n identical Cournot firms, λ equals $1/n$. Thus, the observed market power after 1974 is equivalent to that if there were 1.7 identical Cournot firms (ignoring the problem of a fractional number of firms). Similarly, λ is equivalent to the Herfindahl index when all firms are the same size.

Conclusions

Our flexible nonlinear three-stage least squares model is designed to capture the degree of market power actually exercised by the Philippines without explicitly describing the nature of the decision-making process in the Philippines. Nonetheless, it allows for the measure of market power to shift over time in response to political and other changes.

In particular, the creation in 1973 of the Philippine coconut oil refining and exporting agency (PCA) allowed the Philippine coconut oil export industry to start exercising a substantial amount of its potential dominant firm market power. As a result, the Lerner measure, which reflects the markup of price over marginal cost, more than doubled after 1973. Even in this later period, however, the Philippines is not capturing all its potential market power.

A major remaining question is whether health concerns in importing countries about saturated fats will cause the demand for tropical oils to fall markedly in the future. As of January 1989, four major U.S. food companies announced their plans to switch from tropical to less saturated oils within a few years. If this trend continues, the Philippines may suffer a substantial loss of export revenues.

[Received July 1990; final revision received January 1991.]

References

Baker, Jonathan B., and Timothy F. Bresnahan. "Estimating the Elasticity of Demand Facing a Single Firm: Evidence on Three Brewing Firms." Stanford University Dep. Econ. Work. Pap. No. 54, June 1984.

Bresnahan, Timothy F. "The Oligopoly Solution Concept Is Identified." *Econ. Letters* 10(1982):87–92.

Brown, Deborah J., and Lee F. Schrader. "Cholesterol and Egg Consumption." *Amer. J. Agr. Econ.* 72(1990):548–55.

Bunge, Frederica M. *Indonesia, a Country Study*. Washington DC: American University, Secretary of the Army Area Handbook Stud., Jan. 1984a.

——. *Malaysia, a Country Study*. Washington DC: American University, Secretary of the Army Area Handbook Stud., Jan. 1984b.

Carlton, Dennis W., and Jeffrey M. Perloff. *Modern Industrial Organization*. Glenview IL: Scott, Foresman/Little, Brown, 1990.

Commodity Trade and Price Trends. Baltimore MD: Johns Hopkins University Press for the World Bank, various years.

CRB Commodity Yearbook. Jersey City NJ: Commodity Research Bureau, selected years.

Fruit and Tropical Products. London: Great Britain Commonwealth Secretariat, Commodities Division, various years.

Hawes, Gary. *The Philippine State and the Marcos Regime*. Ithaca NY: Cornell University Press, 1987.

International Financial Statistics. Washington DC: International Monetary Fund, various years.

Just, Richard E., and Wen S. Chern. "Tomatoes, Technology and Oligopsony." *Bell J. Econ.* 11(1980):584–602.

Karp, Larry S., and Jeffrey M. Perloff. "Dynamic Oligopoly in the Rice Export Market." *Rev. Econ. and Statist.* 71(1989a):462–70.

——. "Estimating Market Structure and Tax Incidence: The Japanese Television Market." *J. Indust. Econ.* 37 (1989b):225–39.

Lau, Lawrence. "On Identifying the Degree of Competitiveness from Industry Price and Output Data." *Econ. Letters* 10(1982):93–99.

Philippine Statistical Yearbook. Manila: Republic of the Philippines National Economic and Development Authority, various years.

Readers Guide to Periodic Literature. New York: H. W. Wilson Co., various issues.

Rizek, R. L., S. O. Welsh, R. M. Marston, and E. M. Jackson. "Levels and Sources of Fat in the U.S. Food Supply and in the Diets of Individuals." *Dietary Fats and Health*, ed. E. G. Perkins and W. J. Visek. Champaign IL: American Oil Chemists' Society, 1983.

Spiller, Pablo T., and Edwardo Favaro. "The Effects of Entry Regulation or Oligopolistic Interaction: The Uruguayan Banking Sector." *Rand J. Econ.* 15 (1984):244–54.

Time. "Cookies the Heart Can Love." 23 Jan. 1989, p. 71.

Woodroof, Jasper G. *Coconuts: Production, Processing, Products*. Westport CT: AVI Publishing, 1979.

Yearbook of Labour Statistics. Geneva: International Labour Office, various years.

Federalism, Opportunism, and Multilateral Trade Negotiations in Agriculture

Fred J. Ruppel, Fred O. Boadu, and E. Wesley F. Peterson

When federalist nations are signatories to international economic agreements, potential problems arise because of the inherent conflicts between federal law and legitimate state interests. This paper presents a conceptual framework for analyzing problems surrounding negotiation, ratification, and implementation of international agreements when federations are signatories. The economic model isolates three factors (the variance of state net benefits under an agreement, individual states' opportunity costs associated with the agreement, and state-supported opportunism) as cost-increasing impediments to the successful institution of international economic agreements and highlights opportunism containment as fundamental to credible commitments in international agreements.

Key words: club goods, federalism, GATT, international trade, multilateral trade negotiations, opportunism, public goods, trade liberalization.

Signatories to international economic agreements frequently are national federations. A federation is "a system of government in which central and regional authorities are linked in a mutually interdependent political relationship . . . [and] . . . a balance is maintained such that neither level of government . . . can dictate the decisions of the other, but each can influence, bargain with, and persuade the other" (Vile, p. 199). National federations include, among others, the United States with its fifty member states, Canada with its ten provinces, Switzerland with its twenty-two cantons, and the Soviet Union with its fifteen republics. Supranational federations include the European Community (EC) with its twelve member nations and the Council for Mutual Economic Assistance (CMEA) with its seven Communist Bloc member nations.

Federations pose particular problems in the negotiation, ratification, and implementation of international agreements because the various members of the federation and the federation itself often have divergent interests in the agreement. In international agreements which affect agriculture, constituent interests are particularly prominent. There is much historical precedent for members of federations to seek to shape international agreements related to agriculture as well as to behave opportunistically once the federation has entered into such agreements.[1] Consider the following:

(*a*) Florida tomato growers and Arizona importers of Mexican tomatoes were able to invoke "state interests" to influence their representatives in Washington to work for trade legislation to protect their conflicting interests (Bredahl, Schmitz, and Hillman).

Fred J. Ruppel, Fred O. Boadu, and E. Wesley F. Peterson are, respectively, assistant professors, Department of Agricultural Economics, Texas A&M University, and an associate professor, Department of Agricultural Economics, University of Nebraska. Senior authorship is not assigned.

Texas Agricultural Experiment Station Technical Article No. 25227.

The authors wish to thank C. Ford Runge, Teofilo Ozuna, Ron Griffin, David Bessler, Richard Shumway, and three anonymous reviewers for helpful comments.

[1] Opportunism is defined as "the art, policy, or practice of taking advantage of opportunities or circumstances, especially with little regard for principles or consequences" (*Webster's Ninth New Collegiate Dictionary*, p. 828). Opportunistic behavior attempts to circumvent either the letter or the spirit of the law for personal, political, or economic gain. In a two-party context, opportunistic behavior occurs "when a performing party behaves contrary to the other party's understanding of this contract, but not necessarily contrary to the agreement's explicit terms, leading to a transfer of wealth from the other party to the performer" (Muris, p. 524). When a contract signatory is a multiperson entity, such as a partnership or corporation, opportunism can occur whenever any person who is a representative of the signatory violates the letter or spirit of the agreement. Similarly, when an agreement signatory is a government entity or a civil authority, opportunistic behavior can be manifested by any of the constituents represented by the governing authority. This paper focuses on this latter problem.

(*b*) Baldwin details the influence of congressional representatives from states where sugar production and processing are concentrated on the implementation of key parts of the Tokyo Round nontariff agreements.

(*c*) Texas agricultural commissioner Jim Hightower offered to provide the EC with hormone-free beef following the EC's ban on imports of meat from animals treated with hormonal growth promotants. While the offer did not violate any U.S. laws, it undermined the position of the U.S. Department of Agriculture and the U.S. Trade Representative, thereby pitting federal interests against state interests (*Time*).

(*d*) Conflicts exist between states and the U.S. federal government over food labeling laws, as reflected in California's Proposition 65. These disputes will become very important as efforts to establish international food labeling standards are undertaken (*Washington Post National Weekly Edition*).

(*e*) The issue of states' rights in the regulation of pesticide use is running counter to federal government attempts at international harmonization of environmental concerns in "Big Green," California's Environmental Protection Act of 1990 (*Agrichemical Age*).

These examples show that issues related to state and federal interests in international agreements are common in food and agriculture, as well as in other industries.[2] In particular, the Uruguay round of multilateral trade negotiations (MTN) under the auspices of the General Agreement on Tariffs and Trade (GATT) has specifically targeted agriculture and could lead to international commitments by federal governments that may run counter to the interests of particular members of the federations.

These examples also illustrate the peculiar problems faced by federations in international agreements. Members of a federation may attempt to shape these agreements in order to respond to special interests within their jurisdictions. State influence can be exercised when the agreement is being negotiated, ratified, and/or implemented.

In this paper, particular attention is given to the problems of ratification and implementation of international agreements by federations because members can have the greatest impact in these areas.[3] The main purpose is to develop a conceptual framework to explain the unique problems faced by federalist nations participating in multilateral agreements or international organizations. Aspects of this problem have been treated in the legal and political science literature, but no general framework for analyzing the effects of this problem on international economic agreements has been developed. In fact, economists typically abstract from institutional decision-making structures in their policy analyses and are not very sensitive to the particular problems engendered or endured by federations. Following further introductory comments, we present a conceptual model of multilateral trade negotiation participation for nations which are federations of states. In the third section, a number of bidirectional impacts between negotiated outcomes and state welfare within a federalist structure are examined, and then the concept of opportunism is considered more closely. We argue in the final section that (*a*) credible commitments by federations of states are established only when steps are taken to reduce opportunistic behavior by member states, and (*b*) enforcement of MTN outcomes is much more costly when opportunism is rampant.

Federations in International Agreements

Two fundamental issues lie at the heart of conflicting state and federal interests in international agreements. The first is the lack of effective enforcement mechanisms within international agreements to assure compliance by both the federation and its members. For example, the federation clause in the GATT requires only that national governments take "reasonable actions" to insure compliance by federation members (General Agreement). In republics such as the United States and Canada, the principle of states' rights leaves considerable room for individual states or provinces to attempt to circumvent the disagreeable parts of an international agreement.

The second issue concerns the nature of domestic institutions within nations. Subnational

[2] In the present context and throughout the paper, the term "states" will often generically refer to any component units within federalist nations, such as provinces, cantons, and republics.

[3] Opportunistic behavior during implementation is a classic case of nonmarket failure as discussed by Wolf: "Just as the absence of particular markets accounts for market failure, so nonmarket failures are due to the absence of nonmarket mechanisms for reconciling calculations by decision makers of their private and organizational costs and benefits with total costs and benefits" (p. 112).

governments within federalist systems often have jurisdiction over certain economic activities, and the federal governments may encounter difficulties in attempting to override these regulatory prerogatives. For example, individual states within the United States have the authority to regulate certain aspects of interstate commerce. This authority is particularly notable for fresh agricultural products. Individual states may have particular interests in issues related to the effects of technical regulations (such as labeling and phyto-sanitary rules) on trade in agricultural products. In consideration of an international agreement on the control of the Mediterranean fruit fly, for example, California representatives would have an incentive to influence the agreement in ways that are not consistent with the national interest.

Problems of this nature do not arise in nations without subnational governments. Although differences between particular interests and the broader national interest are also common in unitary states, the lack of subnational administrative units means that those wishing to have their particular interests articulated must utilize special interest groups. This latter avenue is also available to special interests in federations, in addition to their influence with subnational representatives or coalitions of representatives, as in the (Baldwin) sugar example mentioned above. Coalitions of this nature may influence all aspects of international agreements.

To further complicate the situation, a member of a federation often may have its own particular interests independent of those that arise from the coincidence of geographic location or the special interests of various industries or other groups. Situations of this nature are particularly evident in supranational federations, such as the EC, where the individual members retain much stronger separate identities than in national federations such as the United States. Different languages, currencies, customs and cultures all contribute to the existence of stronger divergences between "community" interests and the interests of the member nations. These differences are frequently invoked in cases of opportunistic protectionism; an example is the German beer purity law, the *Reinheitsgebot*. This law, specifying the ingredients legally permitted in beer, dates back to 1516. In 1987, the German government attempted to apply this law to imports of beer from other EC members as well as from other countries. The European Court of Justice blocked this effort on the grounds that it violated EC rules (Peterson and Lyons). Part of the German government's argument for the beer regulation rested on the assertion that German customs included the consumption of copious amounts of beer, more than in other countries, so that German beer drinkers were more likely to suffer adverse effects of any additives that might be contained in non-German beers (*Agra Europe* 1987).

Conceptual Framework

A model of international economic organizations developed by Fratianni and Pattison serves as our starting point for analyzing the behavior of nations and states in international agreements. The Fratianni and Pattison model is related to those derived from the theory of clubs, first articulated by Buchanan in 1965. The theory of clubs explains public goods provision in terms of a group whose preferences are similar and thus acts "as one." Like pure public goods, "club goods" possess some degree of nonrivalry in consumption, although congestion can occur if the number of club members expands indefinitely. Unlike pure public goods, however, club goods typically are characterized by excludability. Although Fratianni and Pattison refer to clubs, they are careful to point out that their model differs from club models because they consider only organizations generating nonexcludable benefits.

In a similar vein, Runge, von Witzke, and Thompson describe international agricultural trade as a public good and its liberalization as a problem of public goods provision, complete with attendant efficiency (free rider) and equity (fair share) problems. They see agricultural negotiations in the GATT as a means of circumventing these problems through the establishment of a system of reciprocal trading rules. We maintain that the GATT can further be viewed as a club, in that the GATT provides benefits that can be withheld from nonmembers because negotiated tariff reductions are available only to signatories of the agreement. However, the GATT differs from the classic clubs because it does not suffer from membership congestion. In fact, the world trading environment is improved as additional countries choose to participate in the GATT, further reducing world tariff barriers.

Within the GATT, some members are unitary states, such as Ghana, while others are federations of states. The benefits and costs of membership in the GATT will differ for different types

of governmental structures. An analogy might be helpful: consider a club in which families join an association, such as a tennis or golf association. All family members are eligible to play, and all must conform to club rules. However, the problems of a head of household with a large, rowdy family inclined to subvert the club rules are different from those of a bachelor who is responsible only for himself.[4] Such institutional issues must be addressed in evaluating the economic consequences of international trade agreements because the problems associated with member states with "large families" differ from those with small ones.

Fratianni and Pattison examined the behavior of member nations of international economic organizations in the market for international cooperation. Previous work had presumed equal cost sharing by participants, with both benefits and costs modeled as functions of the output of the organization. The optimal provision of services in this case was (not unexpectedly) the point where the marginal benefit of the output of the organization was equal to the marginal cost of providing services.

Fratianni and Pattison extended previous work by allowing for country-specific cost functions, with the number of participants and the decision rule (i.e., consensus, unanimity, majority rule, etc.) also included as arguments in each country's cost function. They showed that countries determine the optimum amount of cooperation by equating the marginal cost of the organization to its marginal benefit, with the marginal benefit weighted by the country's share of benefits received divided by its share of the costs. Or stated in another form, each nation's benefit-to-cost share ratio affects its decision to equate the marginal benefit of the club (as a whole) to the club marginal cost. These derivations, with modifications reflecting representative governments in multilateral trade negotiations, are presented in appendix 1A, equations (1) and (1′). Throughout that presentation and in the rest of this paper, we use states within a nation (a federalist structure) to represent constituents who must ratify a negotiated agreement.

The Fratianni and Pattison modification of the cost function can be carried one step further by recognizing that the decision rule is more than simply the process by which the organization itself reaches a decision. Only with a self-executing treaty is the decision binding on the signatories so that the decision rule process is the major cost element. Many MTN agreements, including the GATT, are not self-executing. That is, GATT implementation in general and its application to states within a federal system is not automatic. When agreement signatories are representatives of larger bodies who must ratify the agreement prior to its implementation, the outcome is itself subject to further tests, and the agreement may be voided. The decision rule, although not costless in and of itself, may be a small factor in overall costs if a negotiated agreement can be voided by the constituents of any of the signatories. In such cases the costs of ratification and implementation likely are critical in the realization of effective agreements.

A modification of the Fratianni and Pattison model reflecting ratification and implementation costs in representative governments is presented in appendix 1B. This modified cost function lies at the heart of the economic theory of the federalist state in international economic agreements. Ratification costs (Θ_i) and implementation costs (Ω_{ij}) are both dependent upon member state assessments of the value (to their states) of national participation in an international agreement relative to state-specific benefits without an agreement (Γ_{ij}). The larger the benefits outside an agreement, the more the states will fight national participation in the agreement. Accordingly, any of the j states in the nation has potential impact on ratification and implementation of the agreement.

Ratification of an agreement is further subject to the distribution of benefits between the states (σ^2). An equitable distribution lowers ratification costs; but, if a number of states feel "cheated" by an agreement, they can effectively forestall ratification. Those states that have an agreement forced on them may undermine the agreement by obstructing implementation, especially if their net benefits outside the agreement are substantial. Obviously, implementation costs are inconsequential if ratification costs are prohibitive.[5]

[4] A special thank-you to C. Ford Runge for providing this analogy.

[5] These cost functions (and those in Fratianni and Pattison) do not include transactions costs or the dynamics associated with arriving at the agreement. Accordingly, their model (in the present context) would not describe *ex ante* calculations of expected costs and benefits that would influence the decision to participate in negotiations such as the MTN, nor would it include negotiating costs (or negotiating benefits). Analysis of the negotiation process would require the use of game theory or some other approach to account for strategic behavior and is beyond the scope of this paper. Strategic behavior is also a part of ratification and implementation, and interdependencies are present in all three phases of the agreement process. Our formulation abstracts from much of the strategic behavior associated with international negotiations such as seen in the Uruguay round of MTN.

When ratification and implementation are not automatic, the result of the maximization problem differs from the earlier result with the addition of three terms reflecting indirect increases in the marginal cost facing nation i in the event of a negotiated agreement [equation (3) in appendix 1B]. The first term reflects the cost of ratification of the agreement based on the variance of the net benefits across states and, thus, relates to a concern for equity. The second term reflects the cost of ratification of the agreement based on each state's assessment of its relative benefits in the absence of an agreement. It is a measure of the opportunity cost of the agreement. The third term reflects further costs of implementing a ratified agreement when particular states may have the incentive to violate or circumvent the agreement. This third term is opportunism. The second and third terms appear similar; however, differences in the institutional mechanisms related to agreement ratification and agreement implementation (the Θ_i and Ω_{ij} functions) and the amount of government control over ratification and implementation costs (the parameters α_i and β_i) make the concepts of opportunity costs and opportunism actually quite different. These differences are explored more fully in the next section.

In appendix 1C, the results of state-specific optimization in the face of a negotiated agreement are derived. In essence, individual states consider the same elements as the nation in deciding whether or not to go along with agreements negotiated by the federal government, except their decisions are further weighted by their benefit and cost shares and by changes in those shares. Note that equation (5) reflects individual state optimization. Various groupings of states could also maximize a modified joint objective function. For example, in spite of overwhelming public support against cigarette smoking, the coalition of tobacco-producing states has consistently influenced U.S. farm policy to the advantage of their producers.

Institutional Impacts on International Agreements

The conceptual model set forth in the preceding section and specified in the appendix highlights the interaction between the interests of members of a federation and the federation itself in reaching and carrying out international agreements. The variance of state net benefits, the opportunity costs of the agreement, and the likely payoffs to opportunistic behavior are the critical factors affecting the costs faced by federations entering into international agreements. Before examining these factors more closely, it is useful to contrast the effects of different forms of government on the magnitude of the ratification and implementation costs.

National Government Structure and the Federal Problem

Many types of governing structures are found in federations, ranging from pure democracy to dictatorship. The type of government structure affects how the interests of member states are articulated as well as the overall costs of making decisions. In the model presented in the appendix, these costs are included in the values of the parameters reflecting government control over ratification (α_i) and implementation (β_i) costs. There is no requirement or expectation that the level of government control over the costs of these two phases of the agreement will be the same or even nearly so because national governments may assume very different postures with respect to ratification and implementation. These levels of government control will also vary, *ceteris paribus*, with the type of governing structure and with membership in a suprafederation.

Ratification costs are reduced if the governing structure allows a simple approval process, such as a vote in a representative body with no necessity to poll constituents. On the other hand, a ratification procedure such as that used in the United States to ratify constitutional amendments (two-thirds votes in the House and Senate plus favorable votes by the legislatures of three-fourths of the states) would clearly raise the costs of ratification. Low ratification costs (small values of α_i) might be found in a federation with a unicameral parliamentary structure where representatives vote along strict party lines. A negotiating representative with preordained power to sign a document without *ex post* approval reduces ratification costs to near zero. A dictator might grant this approval to an authorized representative. Surprisingly, the U.S. Congress grants this authority to the president on certain matters, such as the War Powers Act, United Nations votes, and some bilateral trade negotiations.

Low costs associated with the level of government control over implementation (β_i) could relate to a small federation with only a few relatively homogenous states and little or no states' rights clauses in its national body of law. Implementation costs increase with the size and di-

versity of the federation because the federation may then include subunits with well-developed and different local practices, laws, and customs. The heterogeneity of a federation makes it more difficult in democratic systems to control the behavior of member states (see Runge, von Witzke, and Thompson). Canada has long had problems with Quebec, which has very different traditions and customs than the rest of the provinces. Also as the Soviet Union has begun to relax the dictatorial control of the central government, republics within the union have begun acting independently in various ways.

Membership in a suprafederation which must endorse an agreement would likely increase the need for further governmental oversight and/or institutional mechanisms covering both the ratification and implementation phases. In the EC, for example, the supranational federation adds a third layer of decision making to the process of ratifying and implementing international agreements because most of the members of the EC are federations in their own right. Thus, an agreement negotiated by MTN participants must be ratified and implemented by the governing structures of the Community under the influence of the governments of the member nations. Many of these governments will have had to solve federal problems of their own in arriving at a consensus position in the negotiations. The problem in agriculture is particularly acute because of the importance of the Common Agricultural Policy (Peterson and Lyons, Runge and von Witzke). Translating an international agreement on agricultural trade acceptable at the Community level into national law within member nations may be quite complex and costly.

Ratification: Opportunity Costs and the Variance of State Net Benefits

Ratification costs depend on opportunity costs and the variance of state net benefits, as well as on the level of government control. Both opportunity costs and opportunism are dependent upon state-specific net benefits absent an agreement to net benefits within an agreement. However, they differ substantially in time and in the way they are incorporated into the cost equation. Opportunity costs affect ratification inversely. If enough states perceive benefits absent an agreement to greatly exceed benefits within an agreement (Γ_{ij} greater than one), an agreement may be returned to the negotiators without ratification. This could force costly renegotiation depending on the MTN decision rule. However, because of significant government control (as discussed above), dictatorships or parliamentary structures are likely to ratify an agreement even though many or all states have opportunity cost ratios in excess of unity. Although the ratification function in the appendix is written as a function of the summation of the opportunity cost ratios over all j states, all the ratios could be further adjusted by state-specific operators so that weighted net benefit ratios enter into the ratification procedure. This method would be realistic for representative national voting bodies where votes are proportional to state populations.

The variance of state net benefits is positively related to federation size and the number and heterogeneity of states. The variance could also be affected positively or negatively by the number of items in the agreement and the political power of the various state representatives in the national assembly. If power is distributed along party lines, particularly when party lines coincide with geographical corridors or cultural ties, greater variation is likely within the constituent states. This is often the case in parliamentary federations and dictatorships. These conditions likely will result in greater net benefits to loyal states and lesser gains to opposition states. Republics, on the other hand, likely experience smaller variations in total net benefits because trade-offs can occur which satisfy all states to some degree. The possibility of logrolling will even out the distribution of benefits if the agreement contains enough items for reasonable compromise.

Clearly, states will be opposed to decreases in their welfare (G_{ij}) in the event of a negotiated agreement. Reactions to changes in benefit and cost shares are much less predictable because positive welfare gains can be associated with both increases and decreases in the state share of national net benefits, and with numerous combinations of positive and negative changes in state benefit and cost shares. That is, if the "national pie" increase is large enough, a state could realize increases in economic welfare even if its share of national benefits and costs decrease and increase, respectively. *Ceteris paribus,* however, states are more pleased when benefits shares rise and cost shares fall.

Implementation and Opportunism

While issues related to ratification can be crucial in international trade agreements, difficulties with implementation of an agreement are

more common.[6] In federal structures, the major factor adversely affecting implementation is opportunism, those activities by member states or private individuals designed to "get around" the written agreement. The higher the net benefits outside the agreement, the greater will be the ratification opposition and the ensuing implementation opportunism, *ceteris paribus*. However, some activities generating net benefits outside an agreement (F_{ij}) may be clearly prohibited under a new agreement. Engaging in illegal activities for financial gain could not properly be classified as opportunistic. These activities are deducted from F_{ij} before calculating the opportunism ratio, Γ_{ij}. On the other hand, if a large number of these alternative activities are excluded by the negotiated agreement, a state may be more inclined to behave opportunistically. As with ratification costs, high levels of government control over implementation can exert influence or pressure to deny or reduce opportunistic behavior by the states. These attempts by national governments to limit variations on the negotiated agreement lie at the heart of credible commitments in multilateral trade negotiation.

Opportunism and Credible Commitments

The concept of opportunism emerged from the transactions cost literature in reference to governance structures for firms. However, the concept has found useful application in the enforcement of international agreements. With imperfect information and lack of efficacious third-party adjudication and enforcement in the international arena, no country acting individually has an incentive to forgo opportunism (Yarbrough and Yarbrough, p. 131). Opportunistic behavior is subtle, and monitoring costs are high.

Forms of Opportunism

Depending on the type of governmental structure of a signatory nation to an international agreement, three forms of opportunistic behavior can be identified: private opportunism and two types of public or "state-sponsored" opportunism. Private opportunism refers to those (legal) activities by a private individual or firm which are in violation of the spirit of an international agreement to which their country is a signatory. Private opportunism can occur in either a unitary government or a federation and is difficult to distinguish from pure profit maximization.

The first type of public opportunism, "opportunistic protectionism" involves public cheating or reneging on national agreements by the national government through protectionism in violation of negotiated commitments (Yarbrough and Yarbrough, p. 131). Opportunistic protectionism can also occur in countries with both unitary and federal forms of government because, in this case, the central government is itself reneging on the negotiated commitment through either its legislative powers or its lack of enforcement. Many nontariff barriers to trade and other trade restrictions fall under opportunistic protectionism. For example, a nation might institute health and safety laws and thereby limit imports despite being a signatory to a negotiated agreement curtailing or reducing many tariff and nontariff barriers. Recent conflicts within the EC over product definitions and standards illustrate opportunistic behavior. Both Italy and Germany have attempted to prevent imports of pasta and beer (as mentioned above) from other members of the EC on the basis of product definition and despite EC rules against internal barriers to trade (Peterson and Lyons). Opportunistic protectionism often gives rise to retaliation as in the conflict between the United States and the EC over the use of growth-promoting hormones in the production of livestock products (Peterson, Paggi, and Henry).

The second form of public opportunism is unique to federalist systems of government. Under this form, the national or central government does not violate the agreement, but a state within the federation may behave contrary to the spirit of the negotiated agreement in order to transfer wealth to its residents. This form of public opportunism, which clearly falls into the category of rent-seeking activities in international trade (Bredahl, Schmitz and Hillman), differs from that discussed above in several important respects.[7] First, a state within a federa-

[6] In fact, as suggested by Wolf, policy analysis all too often fails to consider problems of implementation which generates "typically large gaps between programs as designed and as executed" (p. 133). In his own analysis, however, Wolf tends to be concerned with the behavior of bureaus and agencies charged with implementing specific policies as opposed to the unique implementation problems confronting national and subnational institutions in a federal context.

[7] A number of similarities exist between this form of opportunism and other public choice concepts, including the "free rider" problem in public goods provision (Runge, von Witzke, and Thompson), the "principle-agent" problem in contract law (Hart and Holmstrom), and the problem of multiple polluters in nonpoint pollution control (Segerson).

tion may legitimately exercise police powers for the protection of health and safety, and the federal government may be barred from interfering in areas of traditional governmental functions (*Garcia* v. *San Antonio*). Thus, policing state opportunism may encounter constitutional constraints and may impose further costs on the federal government. Second, a state within a federation may behave opportunistically relative to an international agreement in order to transfer wealth not only from foreign participants but also from other member states in the federation to its residents. The institutional apparatus required to police this opportunistic rent seeking is more complex than that required to police private and public opportunism by citizens or entities in a unitary government.

Institutional Mechanisms for Policing Opportunism in a Federal System

National governments rely on several mechanisms to police potential opportunistic behavior of states in the federation. Even though the mechanisms may differ in content and quality, some characteristics are common. Policing mechanisms fall into two broad categories: legislation and control of the purse.

(a) Legislation. In federal systems, national law is superior to inconsistent legislation in a member state. In the United States for example, the principle of "pre-emption" bars even identical, consistent, or supplementary state regulation because the federal government has already "occupied the field." This means that an international agreement would preempt any inconsistent state legislation to the extent that the agreement is considered the supreme law of the land. In the EC, Community law takes precedence over national legislation enacted after 1968. A recent European Court of Justice decision prevented a French merchant from labeling his eggs according to the date of lay because of a Community law specifically prohibiting this action. The merchant's appeal that the EC regulation "ran contrary to the fundamental law of consumer information" was denied because of "the supremacy of Community law over national law" (*Agra Europe* 1989).

Although national law is superior to lower level law in most federal nations, in many cases the national governments have given subnational authorities many legislative prerogatives. In the United States, for example, the courts have interpreted the principle of "states' rights" to mean "the freedom of the state to structure integral operations in areas of traditional governmental functions" (*National League*, p. 852). The term "traditional governmental functions," however, is not well defined and may in fact be quite generous. A similar outcome is possible within the Swiss federal system. In Switzerland, the relevant federalism clauses of the constitution have been interpreted quite liberally to mean that cantons possess concurrent powers to sign international agreements that deal with matters under their jurisdiction (Bernier). Another example of the federalism problem in a domestic context surfaces in the Canadian federal structure where the province of Quebec has long been claiming outright international personality status and has thereby raised some difficult constitutional issues in the jurisprudence of Canada.

A second legislative measure for policing opportunism focuses on establishing uniform rules. The courts in the various countries have been the principle enforcers of these rules. The Court of Justice of the EC has consistently used Article 30 of the European Economic Treaty to strike down any legislation by a member nation found inconsistent with the uniform rule. Article 30 states in part, "Quantitative restrictions on importation and all measures with equivalent effect shall . . . be prohibited between Member States."

The equivalent rule in the United States is the dormant Commerce Clause, "dormant" in the sense that legal structures have come into operation as a result of court construction and not through actual legislation. The Commerce Clause has been used in the United States to invalidate state laws concerning barriers to incoming or outgoing trade, taxation of foreign firms, investment codes (such as requirements for locating processing plants), purchasing requirements (similar to "Buy America" rules), and health and safety regulations. Given the rather broad definition of "commerce," the usefulness of the dormant Commerce Clause in policing opportunism becomes apparent. A similar regulation in Canada, the "Trade and Commerce" power has prevented provincial governments from frustrating national legislation.

(b) Control of funding. National governments may also control the behavior of component units by controlling the purse. In Canada, while provincial governments enjoy considerable auton-

omy, the rather larger purse of Agriculture Canada dominates agricultural policy making. It may be used to discipline provinces that behave contrary to the wishes of the national government. In the United States, the spending power of Congress is sometimes used to discipline states that do not act in conformity with the wishes of Congress. For example, highway construction funds have been withheld from states that refuse to raise the local legal drinking age or to enact seat belt laws. This power of Congress has been held constitutional. Similarly, even though the impoundment powers of the president were toned down considerably in 1974, they still remain as another source of discipline. Impoundment power allows the president to refuse to spend or defer the expenditure of funds appropriated by Congress.

Concluding Comments

The conceptual framework sketched above draws attention to the increased costs of negotiating, ratifying, and implementing international agreements among federations characterized by differences in the particular interests of the federation members and the broader interest of the federation itself. While this "federal problem" has been extensively discussed elsewhere, little effort has been made in the economics literature to isolate the important influences on decision making at the subnational and federal levels. This analysis suggests that the cost to a federation of entering into an international agreement increases (*a*) when the variance of net benefits across the states witihin the federation is large, (*b*) when the opportunity cost of participating in the agreement is high for a given state or group of states, and (*c*) when the possibility of realizing gains through opportunistic behavior is great for a particular state or states.

Most of the items listed above are inconsequential once a negotiated agreement is ratified. Opportunism, however, becomes an actual cost only when the agreement becomes law. Some institutional mechanisms are available to federal governments to limit opportunistic behavior by member states. However, while specific measures built into an agreement or domestic provisions aimed at forcing compliance with international agreements are often necessary, these measures may not be enough. Principles of good faith bargaining and institutions to recognize subnational interests formally may be needed to foster credible commitments in international agreements.

The analysis presented in this paper highlights only one component in a complex problem area. Throughout the discussion a number of items have been largely ignored, including the MTN decision rule, the number of signatories to an agreement, and the various types of participant government structures. Moreover, some interaction may occur between the federalism costs described here and such issues as decision rules and the number of participants. The EC with its successive enlargements and its changes in voting rules (from majority rule to unanimity and back to a majority rule) for most decisions, may offer fertile ground for research on these interactions (Runge, von Witzke, and Thompson; Runge and von Witzke). There is also a need for further research on more formal representations of the strategic behavior underlying the increased costs of international agreements. Finally, another aspect of the problem not considered here is the potential influence of exit costs (Hirschman).

International agreements can be compromised if the costs related to federalist structures are sufficiently high. The particular institutional arrangements for dealing with the federal problem may be critical to the success or failure of efforts to promote international cooperation. A truly liberalized world trade regime needs contracting parties to put "teeth" into largely permissive federalism clauses and requires concerted efforts by national governments to streamline national and state trade-related regulations in compliance with GATT rules. Good faith bargaining is crucial to credible commitments. Attempts by federal governments to reduce opportunistic behavior by member units signals a beginning toward this end.

[Received March 1990; final revision received November 1990.]

References

Agra Europe. "Controversy on Egg Labelling." 27 Oct. 1989.

——. "West Germany Must Lift Beer Import Ban." 13 March 1987.

Agrichemical Age. "Probing the 'Circle of Poison'." July 1990.

Baldwin, Robert E. *The Political Economy of U.S. Import Policy*. Cambridge MA: MIT Press, 1985.

Bernier, Ivan. *International Legal Aspects of Federalism*. London: Longman, 1973.

Bredahl, Maury E., Andrew Schmitz, and Jimmye S. Hillman. "Rent Seeking in International Trade: The Great Tomato War." *Amer. J. Agr. Econ.* 69(1987):1–10.

Buchanan, J. M. "An Economic Theory of Clubs." *Economica* 32(1965):1–14.

Fratianni, M., and J. Pattison. "The Economics of International Organizations." *Kyklos* 35(1982):244–61.

Garcia v. *San Antonio Metropolitan Authority*. 469 U.S. 528, 1985.

General Agreement on Tariffs and Trade. *Text of the General Agreement*, Article XXIV (12). Geneva, 1986.

Hart, Oliver, and Bengt Holmstrom. "The Theory of Contracts." *Advances in Economic Theory: Fifth World Congress*, ed. T. F. Bewley. New York: Cambridge University Press, 1987.

Hirschman, Albert O. *Exit, Voice and Loyalty*. Cambridge MA: Harvard University Press, 1970.

Muris, Timothy J. "Opportunistic Behavior and the Law of Contracts." *Minnesota Law Rev.* 65(1981):521–90.

National League of Cities v. *Usury*. 426 U.S. 833, 1976.

Peterson, E. Wesley, F., and Clare B. Lyons. "The Perpetual Agricultural Policy Crisis in the European Community." *Agr. and Human Values* 6(1989):11–21.

Peterson, E. Wesley F., Mechel Paggi, and Guy Henry. "Quality Restrictions as Barriers to Trade: The Case of European Community Regulations on the Use of Hormones." *West. J. Agr. Econ.* 13(1988):82–91.

Runge, C. Ford, and Harald von Witzke. "Institutional Change in the Common Agricultural Policy of the European Community." *Amer. J. Agr. Econ.* 69(1987):213–22.

Runge, C. Ford, Harald von Witzke, and Shelley Thompson. "Liberal Agricultural Trade as a Public Good: Free Trade Versus Free Riding Under GATT." Dep. Agr. and Appl. Econ. Staff Pap. No. P87-11, University of Minnesota, April 1987.

Segerson, Kathleen. "Uncertainty and Incentives for Nonpoint Pollution Control." *J. Environ. Econ. and Manage.* 15(1988):87–98.

Time. "Don't Mess Around with Jim." 13 April 1989, p. 42.

Vile, M. J. C. *The Structure of American Federalism*. London: Oxford University Press, 1961.

Washington Post National Weekly Edition. "Food Labels and Ambiguity." 7–13 May 1990.

Webster's Ninth New Collegiate Dictionary. Springfield MA: Merriam-Webster, 1984.

Wolf, Charles, Jr. "A Theory of Nonmarket Failure: Framework for Implementation Analysis." *J. Law and Econ.* 22(1979):107–39.

Yarbrough, Betty V., and Robert M. Yarbrough. "Institutions for the Governance of Opportunism in International Trade." *J. Law, Econ., and Organizations* 3(1987):129–39.

Appendix

The Fratianni and Pattison Model with Modifications Reflecting Federal Governments in Multilateral Trade Negotiations (MTN)

A. The Fratianni and Pattison Result Restated:

Define

Q is MTN output (a negotiated agreement);

$B_i(Q)$ is nation i's benefit from MTN membership $(\Sigma_i B_i = B)$;

$C_i(Q,N,DR,\Phi_i(\cdot))$ is nation i's cost of MTN membership $(\Sigma_i C_i = C)$, where N is the number of MTN participants, DR is the MTN decision rule (see text), and Φ_i refers to ratification and implementation costs;

G_i is nation i's net benefit of MTN membership, $= B_i - C_i$;

b_i is nation i's share of MTN benefits $= B_i/B$;

c_i is nation i's share of MTN costs $= C_i/C$;

Assume

$$dN = dDR = d\Phi_i = 0.$$

Then,

$$\text{(1)} \qquad \max G_i(Q) \rightarrow \frac{dB_i}{dQ} - \frac{dC_i}{dQ} = 0 \rightarrow \frac{dB_i}{dQ} = \frac{dC_i}{dQ}.$$

Note: Since $B_i = b_i B$ and $C_i = c_i C$, then

$$dB_i = Bdb_i + b_i dB \quad \text{and} \quad dC_i = Cdc_i + c_i dC.$$

Assuming that shares do not change $(db_i = dc_i = 0)$, then

$$\text{(1')} \qquad \frac{b_i dB}{dQ} = \frac{c_i dC}{dQ}, \text{ or } \frac{b_i}{c_i}\frac{dB}{dQ} = \frac{dC}{dQ}.$$

The last term above is the Fratianni and Pattison result.

B. The Fratianni and Pattison Model with Modifications Reflecting Ratification and Implementation Costs

Define further,

$$\Phi_i = \alpha_i \Theta_i \left[\sigma^2(\bar{G}_{ij}), \sum_j \Gamma_{ij} \right] + \beta_i \sum_j \Omega_{ij}(\bar{\Gamma}_{ij}),$$

where

Θ_i is cost of nation i's ratification of the negotiated agreement;

$\sigma^2(\bar{G}_{ij})$ is variance of per capita benefits across states;

$\bar{G}_{ij}$ is per capita net marginal benefit of jth state of ith nation in the event of i's membership in MTN;

F_{ij} is per capita net marginal benefit of jth state of ith nation in the absence of i's membership in MTN;

Γ_{ij} is state-specific ratio of non-MTN to MTN net benefits, $= F_{ij}/G_{ij}$;

$\bar{\Gamma}_{ij}$ is Γ_{ij} as above, with *ex ante* non-MTN benefits excluded by an MTN agreement subtracted from F_{ij};

Ω_{ij} is state-specific cost of implementation of the ratified agreement;

α_i, β_i are measures of government control over ratification and implementation of the agreement, respectively $(0 < \alpha_i, \beta_i < \infty)$.

Assume

$$dN = dDR = 0 \text{ (with } d\Phi_i \neq 0).$$

Then

$$\max B_i(Q) - C_i\left[Q, N, DR, \alpha_i\Theta_i\left[\sigma^2(\bar{G}_{ij}), \sum_j \Gamma_{ij}\right] + \beta_i \sum_j \Omega_{ij}(\bar{\Gamma}_{ij})\right], \tag{2}$$

resulting in

$$\begin{aligned}\frac{dB_i}{dQ} = \frac{dC_i}{dQ} &+ \alpha_i \frac{\delta C_i}{\delta\Theta_i}\frac{\delta\Theta_i}{\delta\sigma^2}\frac{\delta\sigma^2}{\delta\bar{G}_{ij}}\frac{d\bar{G}_{ij}}{dQ} \\ &+ \alpha_i \frac{\delta C_i}{\delta\Theta_i}\sum_j \frac{\delta\Theta_i}{\delta\Gamma_{ij}}\frac{\delta\Gamma_{ij}}{\delta G_{ij}}\frac{dG_{ij}}{dQ} \\ &+ \beta_i \sum_j \frac{\delta C_i}{\delta\Omega_{ij}}\frac{\delta\Omega_{ij}}{\delta\bar{\Gamma}_{ij}}\frac{\delta\bar{\Gamma}_{ij}}{\delta G_{ij}}\frac{dG_{ij}}{dQ}.\end{aligned} \tag{3}$$

C. State-Specific Optimization

Define further,

b_{ij}, c_{ij} are state j's benefit and cost shares of nation i's federation ($\Sigma_j b_{ij} = 1$ and $\Sigma_j c_{ij} = 1$).

Assume $dN = dR = 0$ (with $d\Phi_i \neq 0$); α_i and β_i consistent across all j. Then,

$$\max G_{ij}(Q) = b_{ij}(Q)B_i(Q) - c_{ij}(Q)C_i(\cdot), \tag{4}$$

resulting in

$$\begin{aligned} b_{ij}\frac{dB_i}{dQ} + B_i\frac{db_{ij}}{dQ} = C_i\frac{dc_{ij}}{dQ} &\\ + c_{ij}\Bigg[\frac{dC_i}{dQ} &+ \alpha_i \frac{\delta C_i}{\delta\Theta_i}\frac{\delta\Theta_i}{\delta\sigma^2}\frac{\delta\sigma^2}{\delta\bar{G}_{ij}}\frac{d\bar{G}_{ij}}{dQ} \\ &+ \alpha_i \frac{\delta C_i}{\delta\Theta_i}\sum_j \frac{\delta\Theta_i}{\delta\Gamma_{ij}}\frac{\delta\Gamma_{ij}}{\delta G_{ij}}\frac{dG_{ij}}{dQ} \\ &+ \beta_i \sum_j \frac{\delta C_i}{\delta\Omega_{ij}}\frac{\delta\Omega_{ij}}{\delta\bar{\Gamma}_{ij}}\frac{\delta\bar{\Gamma}_{ij}}{\delta G_{ij}}\frac{dG_{ij}}{dQ}\Bigg].\end{aligned} \tag{5}$$

A Simple Multiperiod Minimum Risk Hedge Model

Kenneth H. Mathews and Duncan M. Holthausen, Jr.

A multiperiod hedging model is developed that is simpler than other multiperiod models in the literature. The model permits periodic adjustment of the hedge while minimizing the producer's profit variance. Minimum risk hedge ratios are calculated for steers, cows, hogs, corn, and soybeans using the full model with hedge adjustments every two months. These ratios are compared to those using the model without periodic hedge adjustments and to a simple single-period model. The results suggest that simple models may work well for simple hedges, while the full model is best for more complex hedging situations such as cross hedges.

Key words: futures markets, hedge ratio, hedging, minimum risk, multiperiod model.

Our purpose in this paper is to develop a multiperiod hedging model in which the hedge can be updated each period. Other multiperiod hedging models (e.g., Anderson and Danthine, Karp) have substantial data requirements which limit their use as viable hedging tools. Our aim is to develop a simpler model that will have practical application. The model is used to calculate minimum risk hedge ratios for steers, cows, hogs, corn, and soybeans, and these ratios are compared with hedge ratios based on a multiperiod model in which the hedge cannot be adjusted each period. Simple minimum risk hedge ratios also are computed for each commodity and compared with the other ratios.

A Simple Multiperiod Hedging Model

Consider a producer (farmer) who will harvest a known amount of a commodity at a known date in the future. The price at which the commodity will be sold at that date is uncertain; hence, the producer's profit from production of the commodity is stochastic. The producer takes a futures position at the initial date, may adjust it at various intermediate dates, and at the final date (the delivery date) offsets the final futures position and sells the commodity in the cash market.

We begin by specifying the model with three trading dates. At the initial date, the hedger takes a futures position, denoted z_1. Any initial margin requirement can be satisfied with treasury bills or some other interest bearing asset at no cost to the hedger.[1] At the second date, the profit or loss on the futures position is determined and is reflected in the producer's margin account. The first-period futures position is then closed and a new futures position, z_2, is taken. At the third date, the delivery date, the firm lifts its hedge (i.e., offsets z_2) and conducts its transactions in the cash market.

Under these assumptions, the firm's profit function is

(1)
$$\pi = m(F_2 - F_1)z_1 + (F_3 - F_2)z_2 + px - c(x),$$

where $m = 1 + i$ is the interest factor (i is the one-period interest rate at which the firm can borrow and lend margin account funds), F_j is the futures price quoted at date j ($j = 1, 2, 3$) for delivery at trading date 3, z_j is the futures position taken at date j, x is the known cash position, p is the stochastic delivery date price for

The authors are, respectively, an agricultural economist with the Economic Research Service, U.S. Department of Agriculture, and a professor of business management, North Carolina State University.

The authors thank Paul Fackler, Kelly Zering, Dave Dickey, and two anonymous referees for many helpful comments on earlier versions of this paper while absolving them of all blame for any errors or shortcomings that remain.

[1] Most major brokers now effectively pay interest on margin account balances so that even small hedgers receive interest on margin balances. We recognize, as Telser, Anderson, Hartzmark, and others have pointed out, that opportunity costs may be associated with funds tied up in margin accounts, even if those funds are earning interest. However, the focus of our paper is on other issues, and thus any opportunity costs associated with margin requirements are ignored.

the cash commodity, and $c(x)$ is the cost function for production of x units of the cash commodity.

At the initial trade date, F_1 is known while F_2, F_3, and p are uncertain. The hedger has subjective estimates about the means of the uncertain prices as well as their variances and covariances. Each futures position z_j is measured in the same units as the cash commodity x and is negative for a short hedge and positive for a long hedge. Risk-averse producers generally are short hedgers, and thus we expect $z_j < 0$ in this model. This relationship means that a rise in the futures price, i.e., $F_{t+1} - F_t > 0$, results in a loss for a short hedger because $(F_{t+1} - F_t)z_t < 0$.

Nonadjustable Hedge

The analysis begins by examining hedges that cannot be adjusted at intermediate trade dates. In the three trade date case, profits are given by equation (1) with $z_1 = z_2 = z$ as shown below,

$$\pi = m(F_2 - F_1)z + (F_3 - F_2)z + px - c(x). \tag{2}$$

In this fixed-hedge case, the firm does not close out its futures position at intermediate dates, but it does earn a profit or loss each period because futures contracts are "marked to market" at each trade date. Profits (or losses) earned at each intermediate date are added to the hedger's margin account where they earn interest. These profits and the interest on them are called "margin returns" later in the paper. In equation (2), the first term on the right-hand side is a margin return.

The producer's objective is to minimize risk as measured by the variance of profit in (2). This assumption is made for a number of reasons. For practical hedging decisions, a mean-variance framework is more understandable and requires less information than a full expected-utility-maximizing model. Second, mean-variance models are equivalent to expected utility maximization if profit is normally distributed and traders have constant absolute risk-averse utility functions. Even if these conditions are not satisfied, mean-variance models can be thought of as quadratic approximations (using Taylor series) of general expected-utility-maximizing models and probably are reasonable proxies for real-world decision models.

The model is set up as a risk minimization model rather than a full mean-variance model for two reasons. First, it is easier to implement a model that does not require knowledge of the decision maker's risk aversion coefficient. Second, and more important, if futures markets are unbiased, the solution to the risk minimization model is the same as the solution to the mean-variance model, as Benninga, Eldor, and Zilcha (1983, 1984) have shown. Because most empirical studies have found little or no systematic bias in futures markets (e.g., Martin and Garcia), this assumption is reasonable for practical applications.

The hedger minimizes the variance of profit, σ_π^2, holding output, x, fixed by choosing the hedge, z, that solves

$$\begin{aligned} \min \sigma_\pi^2 = \min\, [&z^2\sigma_3^2 + (m-1)^2z^2\sigma_2^2 \\ &+ x^2\sigma_p^2 + 2(m-1)z^2\sigma_{23} \\ &+ 2zx\sigma_{3p} + 2(m-1)zx\sigma_{2p}], \end{aligned} \tag{3}$$

where σ_j^2 is the variance of F_j, σ_p^2 is the variance of p, σ_{23} is the covariance between F_2 and F_3, and σ_{jp} is the covariance between F_j and p. The first-order condition for (3) is

$$\begin{aligned} &2z\sigma_3^2 + 2(m-1)^2z\sigma_2^2 + 4(m-1)z\sigma_{23} \\ &\quad + 2x\sigma_{3p} + 2(m-1)x\sigma_{2p} = 0, \end{aligned} \tag{4}$$

from which follows the risk-minimizing solution,

$$z^* = -\frac{x[\sigma_{3p} + (m-1)\sigma_{2p}]}{[\sigma_3^2 + (m-1)^2\sigma_2^2 + 2(m-1)\sigma_{23}]}. \tag{5}$$

The second-order condition for a minimum is

$$2\sigma_3^2 + 2(m-1)^2\sigma_2^2 + 4(m-1)\sigma_{23} > 0. \tag{6}$$

Condition (6) holds if $\sigma_{23} > 0$, and that should always be observed in practice because futures prices at sequential dates are highly positively correlated.

The hedge ratio, r, can be derived from equation (5) by dividing both sides by $-x$:

$$\begin{aligned} r &= -\frac{z^*}{x} \\ &= \frac{[\sigma_{3p} + (m-1)\sigma_{2p}]}{[\sigma_3^2 + (m-1)^2\sigma_2^2 + 2(m-1)\sigma_{23}]}. \end{aligned} \tag{7}$$

If margin returns are ignored, the terms involving F_2 would be dropped from the profit function (2), and the minimum risk hedge ratio would be

$$r_s = \frac{\sigma_{3p}}{\sigma_3^2}. \tag{8}$$

This well-known result in the literature (Kahl), is henceforth called the "standard" hedge ratio, r_s.

Because margin returns introduce additional variability into the profit function, one might think that the hedge ratio incorporating margin returns would be less than the standard ratio. However, this is not necessarily so, as can be seen by comparing r and r_s in equations (7) and (8). If the covariances are positive, as would be expected,[2] the ratio incorporating margin returns, r, will be smaller than r_s if condition (9) is satisfied:[3]

$$(9) \qquad (m-1)\frac{\sigma_{3p}\sigma_2^2}{\sigma_{2p}\sigma_3^2} + 2\left[\frac{\sigma_{23}\sigma_{3p}}{\sigma_{2p}\sigma_3^2}\right] > 1.$$

We argue below that condition (9) generally will be satisfied in practice; thus, the hedge ratio is reduced by taking margin returns into account. First, notice that the first term on the left side of (9) will be small but positive because $(m - 1)$ equals the one-period interest rate, i, and the variances and covariances are all positive. Second, if the futures price at delivery, F_3, and the cash price, p, are highly correlated (as is usually the case), then σ_{23} will be approximately equal to σ_{2p}.[4] Cancelling them leaves $\sigma_{3p}/\sigma_3^2 = r_s$ as the term in the square brackets in (9). Thus, as long as r_s is .5 or greater, condition (9) should be satisfied. Because most empirical minimum risk hedge ratios computed using r_s are greater than .5, the hedge ratios for most commodities are expected to decline when margin returns are considered. This is true for the five commodities we studied, although the differences are small (see table 1).

A natural extension of the three-trade-date model is to increase the number of interim dates because futures contracts are actually marked to market on a daily basis. The minimum risk hedge ratio for the general n trade date case is

$$(10) \qquad r_n = \left[\sigma_{np} + (m-1)\sum_{j=2}^{n-1} m^{(n-1-j)}\sigma_{jp}\right] \Bigg/ \left\{\sigma_n^2 + (m-1)\left[\sum_{j=2}^{n-1}[2m^{(n-1-j)}\sigma_{nj} + (m-1)m^{2(n-1-j)}\sigma_j^2] + 2(m-1)\sum_{k=1}^{n-3}\sum_{j=2}^{n-1-k} m^{k-1}m^{(n-1-j)}\sigma_{n-k,j}\right]\right\}.$$

Empirical Estimation of Hedge Ratios

In this section, hedge ratios are estimated for a diverse group of commodities, both storable and nonstorable, that represent the continuum from relatively pure hedges to cross hedges. The relevant variances and covariances are estimated for each commodity, and minimum risk hedge ratios for six-month hedging horizons are computed using equation (8) for r_s and equation (10) for r_n with $n = 7$.[5]

The commodities are live cattle, cows, hogs, corn, and soybeans. There are sixty-one live cattle contracts (Dec. 1976–Dec. 1986) that are used for both the live cattle and the cows, sixty-six live hog contracts (Feb. 1976–Dec. 1986), forty-eight corn contracts (March 1975–Dec. 1986) and seventy-two soybean contracts (Jan. 1975–Nov. 1986) in the data set. For each contract, the data consist of the cash and futures price on the first day of the month of contract delivery plus futures prices on the first trading day of

Table 1. Estimated Six-Month Hedge Ratios

Commodity	Standard Model	Margin Return Model[a]
Steers	.990	.980
Cows[b]	.845	.842
Hogs	.933	.920
Corn	.964	.944
Soybeans	.973	.959

[a] Based on 7 trading dates (including the initial and delivery dates) at one-month intervals over a 6-month period using an annual interest rate of 8%.

[b] Uses $F_1 - 16.7541$ instead of F_1 as the predicted cash price.

[2] The estimated covariances are all positive and generally decrease with time separation. The three covariances (σ_{23}, σ_{2p} and σ_{3p}) are (11.42, 13.52, 45.98) for steers, (11.42, 20.54, 39.27) for cows, (26.80, 26.29, 62.16) for hogs, (.106, .098, .210) for corn, and (.704, .676, 1.592) for soybeans. The associated correlation coefficients range from .376 to .986.

[3] Condition (9) is derived by setting the expression for r in (7) less than the expression for r_s in (8), multiplying both sides of the inequality by σ_3^2/σ_{3p} and simplifying.

[4] We tested for equality of σ_{2p} and σ_{23} in the data and in all cases found no significant differences with all t-values less than .4 in absolute value.

[5] All empirical hedges considered in this paper are six-month hedges. For $n = 3$, there are three trading dates and two three-month intervals between trading dates. For $n = 7$, there are seven trading dates and six one-month intervals between trading dates. The standard hedge ratio, r_s, is the case when $n = 2$, and there are two trading dates with a six-month interval between them.

each month for the six months prior to the delivery month. Thus, seven futures prices and one cash price are recorded for each contract. For example, the seven futures prices associated with the November 1986 soybean contract are dated in November, October, September, August, July, June, and May of 1986, and the cash price is the November 1986 price.

All livestock futures prices are from the Chicago Mercantile Exchange *Yearbook* or the *Wall Street Journal*, and all grain futures are from the Chicago Board of Trade *Statistical Annual* or the *Wall Street Journal*. Corresponding cash prices are Texas Panhandle–Western Oklahoma 1,050–1,200 pound, 70%–85% choice slaughter steers; North Carolina hog buying station prices for 180–240 pound slaughter hogs; Number 2 yellow corn at Goldsboro, North Carolina; and Number 1 yellow soybeans at Raleigh, North Carolina. For cows, we use cash prices for breaking utility and commercial grade slaughter cows for either Turnersburg or Siler City, North Carolina, depending on which market sale date was closer to (but after) the first trading day of the delivery month. The cow prices are analyzed with live cattle futures to provide a cross-hedge situation for a local market. All cash steer prices are from *Texas Livestock Market News* or *Livestock Meat Wool Market News*. All North Carolina cash prices are from the *North Carolina Livestock Market Report* or the *Market Grain Report*.

Except for locational differences in cash prices, recent empirical work supports the hypothesis that futures prices are unbiased forecasts of delivery period futures and cash prices (e.g., Martin and Garcia and our tests on the sample data).[6] Thus, we assume that the hedger will use the initial trade date futures price, F_1, as a forecast for all succeeding futures prices.

The hedger is assumed to have a subjective joint probability distribution on the set of futures prices, $F_2, \ldots, F_n$, and the delivery cash price, p, conditional on the information available at the initial trade date. As Peck, and Myers and Thompson have pointed out, the conditional variances and covariances of that joint distribution are the ones that must be estimated. Using F_1 as the expectation of each futures and cash price (except for cows where we used $F_1 - 16.7541$ to adjust for bias), the variances and covariances were calculated using Peck's method of mean products of forecast errors. Thus, the typical calculation was of the form

$$(11) \qquad \sigma_{ij} = \frac{1}{T}\sum_{t=1}^{T} (F_{it} - F_{1t})(F_{jt} - F_{1t})$$

for all trading dates i and j subsequent to the initial trade date. When $i = j$, (11) is a variance; when i and j are not the same, (11) is a covariance; when p_t is substituted for F_{jt}, (11) is the cash-futures covariance, σ_{ip}. The additional subscript t indexes the observations (contracts), and T is the number of observations in the sample which varies from forty-eight for corn to seventy-two for soybeans.[7]

Estimated six-month hedge ratios using both the standard and the margin return models are presented in table 1. All the ratios are less than, but close to, one except for the cross-hedge for cows. In every case, the risk-minimizing hedge ratio drops when margin returns are taken into account. However, the magnitude of these effects is small, corroborating Nelson's and Alexander, Musser, and Mason's findings that margin costs and revenues are not large relative to the other gains and losses faced by hedgers.[8]

Updating the Hedge Ratio over Time

In this section, we return to the general model given in (1) and allow the hedger to adjust the hedge at each trade date. The hedger is assumed to minimize the variance of profit at each trade date, and thus a recursive solution method is required.[9] To find the risk-minimizing hedge at the initial trade date, z_1, the hedger must know

[6] By unbiasedness we mean that the mean prediction error, $E(F_t - F_1)$ for futures and $E(p - F_1)$ for cash, is zero. We tested for unbiasedness in each futures and cash market and found bias only for the cow market in North Carolina. The cow market was also the only market with a demonstrable nonzero basis. This is not unexpected because the futures market is used as a cross hedge for the cow market. The average prediction error for cow cash prices was −16.7541¢ with a t-value of −16.333.

[7] For example, the soybean covariance $\sigma_{27} = .2044$ is calculated as $(1/72)[(F_{21} - F_{11})(F_{71} - F_{11}) + \ldots + (F_{2,72} - F_{1,72})(F_{7,72} - F_{1,72})] = (1/72)[(8.62 - 5.93)(7.08 - 5.93) + \ldots + (5.0525 - 5.24)(5.01 - 5.24)]$.

[8] The results likely do not capture the extreme price moves that occurred between trading dates because they are based on marking to market once each month while actual futures markets mark to market daily. To test whether this biases our results, we calculated hedge ratios assuming longer marking to market intervals of 2 and 3 months, and we simulated hedge ratios with shorter marking to market intervals including daily intervals (see Mathews for details). All of these ratios were within .012 of the ratios reported in table 1. Thus, it does not appear that the choice of monthly intervals has important effects on the calculation of the hedge ratios.

[9] This is the standard solution method for dynamic programming problems and was employed by Anderson and Danthine in their more general multiperiod expected utility-maximizing model.

the minimum risk hedge at the second date, z_2. Once z_2 is determined, it is relatively easy to solve for z_1. To make the model tractable, the values for all variances and covariances are assumed known by the hedger at the initial trade date. This assumption means that hedgers will not revise their estimates of the variances and covariances based on recent observations as they move through time from the initial trade date to the delivery date. While this assumption makes the model less general than Anderson and Danthine, it is a reasonable description of the information set most hedgers hold, and it allows us to employ the same data set used previously to compute all the variances and covariances required. Even with this simplifying assumption, however, many more variances and covariances must be estimated than was the case in the simpler model.

Working backwards, the hedger first determines the risk-minimizing hedge at the trade date just prior to delivery, which is date two in this three-date model. The profit at that date is

$$\pi = (F_3 - F_2)z_2 + px - c(x), \tag{12}$$

where only F_3 and p are stochastic. The risk-minimizing hedge at date two is

$$z_2 = -x\frac{(\sigma_{3p}|F_2)}{(\sigma_3^2|F_2)} = -xr_2, \tag{13}$$

where the notation $(\cdot\,|F_2)$ indicates that the variances and covariances are based on forcasts using F_2. This point is subtle, but important. In earlier sections of this paper, σ_{3p}, for example, was a covariance between the delivery date futures price and the cash price based on forecasts for F_3 and p equal to F_1. Thus, the prices in the covariance were two periods in the future. The notation $(\sigma_{3p}|F_2)$ indicates that the covariance of interest concerns the delivery futures price and the cash price based on a forecast of F_2 for each price. Thus, the prices in this covariance are only one period in the future.

Substituting the expression for z_2 from equation (13) into the profit equation (1), we can find the variance of profit at the initial trade date,

$$\begin{aligned}\sigma_\pi^2 = {} & x^2r_2^2\sigma_3^2 + (mz_1 + xr_2)^2\sigma_2^2 \\ & + x^2\sigma_p^2 - 2xr_2(mz_1 + xr_2)\sigma_{23} \\ & - 2x^2r_2\sigma_{3p} + 2x(mz_1 + xr_2)\sigma_{2p},\end{aligned} \tag{14}$$

where all variances and covariances are based on knowledge of F_1 only, and r_2 refers to the hedge ratio given by (13).

Taking the first-order condition of (14) and solving for the initial risk-minimizing hedge ratio gives

$$r_1 = \frac{r_2}{m}\left[1 - \frac{\sigma_{23}}{\sigma_2^2}\right] + \frac{\sigma_{2p}}{m\sigma_2^2}. \tag{15}$$

From equation (15) we can see that, in general, the risk-minimizing hedge ratio will change over time, but the direction and magnitude of change are ambiguous. Anderson and Danthine come to the same conclusion. If, however, basis risk does not exist; that is, if $p = F_3$ (implying $\sigma_{2p} = \sigma_{23}$ and $\sigma_{3p} = \sigma_3^2$), then $r_2 = 1$ and consequently $r_1 = r_2/m$. In this case the hedge increases over time since $r_1 < 1$ and $r_2 = 1$.

The full seven-trade-date version of this model contains too many variances and covariances for us to obtain reliable estimates with the sample sizes available. Thus, we estimate a four-trade-date version instead. With four trading dates, the hedger revises the hedge every two months. Thus, the original hedge is placed six months before delivery, adjustments are made four months and two months before delivery, and the hedge is closed in the delivery month. Two months may well be a reasonable length of time between hedge revisions in practice because brokerage commissions would make more frequent revisions increasingly expensive. The hedge ratios for the four-trade-date model are

$$r_3 = \frac{(\sigma_{4p}|F_3)}{(\sigma_4^2|F_3)}$$

$$r_2 = \frac{r_3}{m}\left[1 - \frac{(\sigma_{34}|F_2)}{(\sigma_3^2|F_2)}\right] + \frac{(\sigma_{3p}|F_2)}{m(\sigma_3^2|F_2)}$$

$$r_1 = \frac{r_3}{m^2}\left[\frac{\sigma_{23} - \sigma_{24}}{\sigma_2^2}\right] + \frac{r_2}{m}\left[1 - \frac{\sigma_{23}}{\sigma_2^2}\right] + \frac{\sigma_{2p}}{m^2\sigma_2^2},$$

where r_3 is the initial hedge placed six months prior to delivery, r_2 is the adjusted hedge placed four months before delivery, and r_1 is the final adjusted hedge made two months before delivery. The conditional variances and covariances, $(\sigma_{ij}|F_k)$, are calculated as in (11) with the substitution of F_{kt} for F_{1t}.

Estimated minimum risk hedge ratios in the four-trade-date model for the sample of commodities are presented in table 2. These results have several interesting patterns. Hedge ratios for steers and cows decrease as the delivery date draws near, while the ratios for hogs and soy-

Table 2. Estimated Hedge Ratios Over a Six-Month Time Period

Commodity	r_1	r_2	r_3
Steers	1.020	1.020	.928
Cows[a]	1.341	.873	.557
Hogs	.912	.920	.942
Corn	.962	1.016	.899
Soybeans	.940	.965	.983

Note: Based on 4 trading dates (including the initial and delivery dates) at 2-month intervals over a 6-month period using an annual interest rate of 8%; r_1 is the initial hedge 6 months prior to delivery, r_2 is 4 months prior to delivery, and r_3 is 2 months prior to delivery.
[a] Each futures price was adjusted by 16.7541 to forecast the cash price.

beans increase. The hedge ratio for corn first increases and then decreases, with the final ratio less than the initial one. Except for cows, the changes are modest, which suggest that a fixed hedge ratio over the entire hedging period may well be optimal when brokerage costs are considered. The most interesting hedge ratios are for the cross hedge on cows, where the ratio declines from 1.341 at the initial date to .557 at the final date. This pattern reflects the co-movement of live cattle and cow prices over long time periods but suggests that basis risk becomes increasingly important as the delivery date approaches. Thus, the hedger finds that the live cattle futures contract becomes less effective in reducing profit variance through time, which leads to a reduction in the hedge ratio as delivery nears.

Conclusions

The multiperiod hedging model developed in this paper is simpler to use and has fewer data requirements than others currently in the literature. The model was used with and without adjustable hedges each period to calculate risk-minimizing hedge ratios for steers, cows, hogs, corn, and soybeans. These ratios were compared with each other and with simple minimum risk hedge ratios for each of the commodities. Little difference was found between the hedge ratios implied by the multiperiod, nonadjustable hedge model and the simple minimum risk hedge model. The multiperiod model with adjustable hedges did give very different results from the other models in the case of cows, which was a cross-hedge situation. These results suggest that simple hedging models rather than more sophisticated multiperiod models may closely approximate minimum risk hedge ratios in many cases, but the simple models can be misleading in more complex situations such as cross hedging.

[Received January 1990; final revision received January 1991.]

References

Alexander, V. J., W. N. Musser, and G. Mason. "Futures Markets and Firm Decisions Under Price, Production, and Financial Uncertainty." *S. J. Agr. Econ.* 18(1986):39–49.

Anderson, R. W. "Comments on 'Margins and Futures Contracts'." *J. Futures Mkts.* 1(1981):259–64.

Anderson, R. W., and J. P. Danthine. "The Time Pattern of Hedging and the Volatility of Futures Prices." *Rev. Econ. Stud.* 50(1983):249–66.

Benninga, S., R. Eldor, and I. Zilcha. "Optimal Hedging in the Futures Market Under Price Uncertainty." *Econ. Letters* 13(1983):141–45.

——. "The Optimal Hedge Ratio in Unbiased Futures Markets." *J. Futures Mkts.* 4(1984):155–59.

Chicago Board of Trade. *Statist. J.* Chicago, various issues 1975–86.

Chicago Mercantile Exchange. *Yearbook.* Chicago, various issues 1975–82.

Hartzmark, M. L. "The Effects of Changing Margin Levels on Futures Market Activity, the Composition of Traders in the Market, and Price Performance." *J. Bus.* 59(1986):S147–80.

Kahl, K. H. "Determination of the Recommended Hedging Ratio." *Amer. J. Agr. Econ.* 65(1983):603–5.

Karp, L. A. "Methods for Selecting the Optimal Dynamic Hedge When Production Is Stochastic." *Amer. J. Agr. Econ.* 69(1987):647–57.

Martin, L., and P. Garcia. "The Price-Forecasting Performance of Futures Markets for Live Cattle and Hogs: A Disaggregated Analysis." *Amer. J. Agr. Econ.* 63(1981):209–15.

Mathews, K. H. "Minimum Risk Hedge Ratios." Ph.D. thesis, North Carolina State University, 1989.

Myers, R. J., and S. R. Thompson. "Generalized Optimal Hedge Ratio Estimation." *Amer. J. Agr. Econ.* 71 (1989):858–68.

Nelson, R. D. "Forward and Futures Contracts As Preharvest Commodity Marketing Instruments." *Amer. J. Agr. Econ.* 67(1985):15–23.

North Carolina Department of Agriculture, Market News Section, Division of Marketing. *Market Grain Report.* Raleigh, various issues 1976–86.

——. *NC Livestock Market Report.* Raleigh, various issues 1976–86.

Peck, A. E. "Hedging and Income Stability: Concepts, Implications, and an Example." *Amer. J. Agr. Econ.* 57(1975):410–19.

Telser, L. G. "Margins and Futures Contracts." *J. Futures Mkts.* 1(1981):225–53.

Texas Department of Agriculture. *Texas Livestock Market News*. Austin, various issues 1975–84.

U.S. Department of Agriculture, Agricultural Marketing Service. *Livestock Meat Wool Market News*. Washington DC, various issues.

U.S. Department of Agriculture, Economic Research Service. *Livestock and Poultry Situation and Outlook*. Washington DC, various issues 1981–88.

——. *Livestock and Meat Outlook*. Washington DC, various issues.

Wall Street Journal, various issues.

Farm Labor Legislation: A Computer Program to Assist Growers

Jeffrey Alwang, David Wooddall-Gainey, and Thomas G. Johnson

Labor recruitment and management is critical to agricultural production. Dependence on hired labor is growing, even in states and regions where farm labor needs were traditionally met by family members. Employment in agriculture is governed by a large number of complex federal and state regulations. A computerized information system designed to facilitate compliance with these regulations is described. A user survey shows that the system is widely and effectively used.

Key words: farm labor, hypertext, legislation, Virginia.

The continued supply of labor is critical to agriculture in the United States. Trends indicate that reliance on hired labor is increasing even in areas where most labor needs were traditionally met by family members.[1] Concurrently, some areas of the country are experiencing declining supplies of hired labor as nonfarm job opportunities grow. These patterns create the need to effectively recruit and manage farm labor. An element of labor recruitment and management is familiarity with the large number of state and federal laws governing employment in agriculture. Compliance with these laws can be costly but reduces the risk of penalties from fines or lawsuits and also may increase the year-to-year reliability of the labor supply. This paper describes a computer system currently being used in Virginia which was developed to enhance grower compliance.

Forces leading to increased reliance on hired labor, such as trends toward larger farms, are likely to continue. At the same time, the supply of farm workers is contracting in many parts of the country as nonfarm job opportunities, especially in low-skilled services, grow. In addition, if the Immigration Reform and Control Act of 1986 (IRCA) is effective, it may reduce much of the replenishment supply of farm workers.[2] The simultaneous trends toward increased dependence on hired labor and shrinking supplies of legal farm workers create new opportunities and burdens for employers. Farmers who can recruit and manage legal laborers effectively will reap economic benefits from doing so.

A major obstacle to effective labor management is the need to comply with the myriad of state and federal laws and regulations governing employment in agriculture. These laws are often complex and confusing, and lack of understanding is one barrier to effective compliance. This lack of understanding is created by unfamiliarity, complex and changing exemptions, and cross references between the laws. Areas without adequate supplies of local workers also may begin to rely on hired migrants, for whom additional legal protections exist.

Farmers have obvious incentives to refrain from complying because there are often costs associated with it. They thus make decisions considering the expected costs of being caught (by enforcement agencies) or being sued (by employees), balanced against the costs of compli-

Jeffrey Alwang, David Wooddall-Gainey, and Thomas G. Johnson are, respectively, an assistant professor, a programmer/analyst, and an associate professor, Department of Agricultural Economics, Virginia Polytechnic Institute and State University.

The authors thank George McDowell and the anonymous *Journal* referees for helpful comments on earlier drafts of this paper.

[1] Nationally, hired labor as a percentage of total farm employment was relatively constant at 25% from 1910 to 1970. After 1970, it trended upward to 35% in 1980 (Whitener Smith and Coltrane). Since 1980, while total labor on farms has declined, numbers of hired farm workers and the total days worked by hired labor have increased (Oliveira and Cox).

[2] IRCA was initially expected to reduce the supply of agricultural labor by 10% to 15%. Studies of IRCA's impact have indicated that minor adjustments are occurring, but that major disruptions have been avoided (U.S. GAO, Martin and Taylor).

ance. A benefit of compliance can be increased worker retention and lower recruitment costs. Extension's role is to improve information flows to the farmer, reducing the costs of compliance and enabling more informed decision making.

Researchers and extension agents recognize the need for positive educational efforts. Some states responded by producing handbooks and seminars designed to educate growers to become better equipped to comply.[3] These efforts improve grower access to local and migrant labor and reduce many of the risks associated with their employment.

In Virginia, the problem of preparing growers to comply with these regulations was tackled differently. A computerized catalog of applicable state and federal laws was created for use in extension and employment service offices. This catalog contains information similar to that in the labor manuals from other states, but access to information and ease of use are enhanced by the computerized format. The resulting package is the only labor law system using hypertext microcomputer software technology which speeds up and flexibly organizes access to the regulations. The system, called Migrant Labor Law (MILAW), is described and evaluated in this paper.

The paper is organized as follows. Legislation governing agricultural employment briefly described. Then, a technical description of the MILAW program is given. Finally, the effectiveness of the MILAW program is evaluated.

Federal and State Legislation

Many state and federal laws have been designed to protect worker's rights. Some of these laws consider the particular conditions of agricultural employment; an example is the Migrant and Seasonal Agricultural Workers Protection Act (MSPA), which was designed specifically for farm workers. Others were modified to mitigate any possible adverse effects by providing specific exemptions or special conditions for agricultural employers. These statutes and regulations are summarized below. This review is intended to illustrate the extent and complexity of these laws.

The *Immigration Reform and Control Act of 1989* (IRCA) was designed to reduce the number of illegal aliens entering the United States. Employers are required to verify their employees' identity and eligibility for work in the United States, avoid discrimination against "foreign sounding" workers, report certain types of workers, and maintain specific records. The key IRCA provision is the establishment of identity, which requires employers to become familiar with a large number of documents that workers possess.

IRCA contains the H-2A program, which allows growers who cannot find workers in the United States to contract with alien labor for specified periods. Contracting with workers requires extensive paperwork and detailed knowledge of application procedures.

The *Migrant and Seasonal Agricultural Workers Protection Act of 1983* (MSPA) provides protections for agricultural workers, agricultural associations, and agricultural employers. Employers who are subject to MSPA must provide their workers with written terms and conditions of employment, comply with specified housing and employment conditions, and keep certain records. MSPA can become very complicated for growers because it contains complex exemptions and a wide ranging set of requirements.

The *Occupation Safety and Health Act of 1970* (OSHA) is designed to ensure safe and healthful working conditions in many occupations. The act provides safety standards in agriculture for temporary labor camps, field sanitation facilities, machinery guards and shields, operation of equipment, and hazardous chemicals. OSHA regulations are enforced in Virginia under the state plan VOSH.

The *Fair Labor Standards Act of 1938* (FLSA) amended numerous times since passage, provides guidelines under federal law for minimum wages, maximum hours, and child labor.

Other laws governing agricultural employment, include, but are not limited to worker's compensation insurance, rules for providing unemployment insurance, and income tax and social security withholding requirements. In the past, agricultural employers were exempted from many of these. Recently, many of these exemptions have been removed.

The changing legislation and exemptions to it require continuous adaptation by employers. The extent and coverage of legislation vary from state to state. In addition, sometimes conflicting exemptions increase the burden to the farmer.

---

[3] Becker and Parsons, Covey, and Rosenberg and Egan are examples.

The MILAW System

The problem described above created the need to prepare farmers, who had little experience in competing for new sources of labor, to comply with the large number of state and federal regulations governing agricultural employment. The quantity and high degree of complexity of the information required simplified access. Alternative solutions exist such as the extension manuals mentioned above.

An evaluation of these manuals led to the conclusion that computer software could be developed to overcome some of the problems of the printed approach. The Pennsylvania state manual (Becker and Parsons) was extremely detailed. The detail made access to the regulations complicated and time consuming. Cross references in some of the laws made it necessary to access two entirely different sections of *Federal Register* text to understand the implications of the regulations.[4] The Florida manual, on the other hand, was compact and easily accessible, but incomplete, and in some cases the lack of detail led to misleading interpretations. MILAW represents a workable compromise between detail and ease of access.

MILAW is a database of federal and Virginia regulations and their interpretations that affect agricultural employment. It uses hypertext, as implemented by the First Class Fusion/HT software package, to facilitate the structure, access, and display of text. Briefly, hypertext may be understood as an electronic catalog through which cards of text are linked together in a predetermined fashion and, based upon end-user selection, displayed. Potential hypertext applications include card catalogs in libraries, encyclopedias, dictionaries, or, as in MILAW, regulations.

The advantages of hypertext stem from its ease of use. As described below, operating MILAW requires few computer skills. Training can focus on the regulations or the program content and not on learning a software package. Hardware needs are minimal; the program requires an IBM PC-compatible or PS/2-compatible computer running DOS version 2.0 or higher with 340K RAM and at least 700K available bytes on a hard drive.

Structure of MILAW

MILAW contains approximately eighty files: Seventy-five text files, one knowledge base, assorted batch files for execution and installation, and the runtime program HTRUN.EXE of First Class Fusion/HT. There are eleven major subject areas included: IRCA, migrant labor camps, field sanitation, VOSH (OSHA), MSPA, minimum wage, child labor, unemployment insurance, worker's compensation, and federal and state taxes.

Access to any subject area is granted through an opening menu. The user moves the cursor with the arrow keys to the desired subject area and then presses the return or enter key. With each choice, a new menu appears from which the user selects in the same manner as before. This branching process continues until the user reaches the desired text or the end of the respective path.

Throughout this branching process, the cursor may be moved to predetermined areas of the screen. Sometimes these areas are menu items, while at other times they are highlighted sections of text embedded within the current display. In either case they are called "buttons." One moves the cursor to a button and then, by pressing the return or enter key, selects the button. The system then branches to the section referenced by the button.

While viewing particular subject areas, three related types of information may be accessed by using function keys: related forms (F4), the source of MILAW's information (F5), and contacts for additional information (F6). At any time, the requested material is displayed by pressing these function keys. Any panel of text may be printed by moving the cursor to the print button and pressing the return or enter key.

Use of MILAW

The following example demonstrates MILAW's ease of use. While following this example, several things should be kept in mind. Text has been removed from each of the screens; the actual screens in the program contain much more information. Once a subject area menu, e.g., VOSH, is displayed, successive screens cascade down one line from the previous screen. Each screen contains a print button on the bottom left. The contents of the current screen may be printed by moving the cursor to this button and pressing

[4] For example, MSPA has exemptions for small businesses whose definition includes a reference to the "500 man-day provision." This provision is from the FLSA and not from MSPA. Cross linking between the two acts is needed if the small business exemption to MSPA is to be understood properly.

"Enter." Finally, the arrows have been added for clarity.

Upon entering MILAW one sees the two opening screens: a title page and then a disclaimer page. Figure 1 shows the main menu, which appears after the disclaimer page. The cursor may be moved to any of the listed topics. In this example VOSH was selected by moving the cursor to the word VOSH with the arrow keys and then pressing the return key. Figure 2 shows the screen which appears after doing so. If the "Introduction" is selected, the screen shown in figure 3 will appear.

The screen shown in figure 3 contains no menu; however, some sections of text are highlighted as buttons, e.g., the word VOSH on the first line. If the cursor is moved to this text and the item selected, a screen appears which describes the role of VOSH and its relationship to OSHA.

The system is easy to use; only three keys plus the function keys are needed. Many of the regulations in MILAW reference particular forms either for informational purposes or as requisites for compliance. All such forms, except federal tax and Social Security forms, are included in an accompanying *Forms Book*. They may be photocopied for reference or used as originals. The forms files in MILAW, activated by pressing F4 or selecting a particular form in the context of particular subject area text, will display the form title and location in the *Forms Book*.

Organization of MILAW

In order to exploit the advantages of hypertext, organization of the material was critical. Each subject area was organized into a common format, with some common subheadings and some subheadings specific to each subject area. The differences between the laws made this organization complicated; each subject area was decomposed and reorganized into common subheadings and subject area-specific subheadings. This organization greatly enhances access to the information.

Examples of frequently used subheadings are "Introduction" and "Terms," which are found in nearly all the subject areas. The "Introduction" subheading contains a concise summary of the subject area, including an overview of who must comply, what requirements exist, and any special provisions.

Each "Terms" subheading contains a menu of terms. By entering a specific term, one is provided with its definition (from the *Federal Register*) within the context of that particular subject area. These terms may be used throughout the subject area and are generally inserted as buttons. Whenever a term is encountered in a subject area, its definition can be called up by activating the button.

The "Terms" subheading is an essential element in the access to the laws provided by MILAW. Often, these terms are complex; the flexible access lets the user refer to the definitions when necessary. For example, in several of its subheadings, the subject area IRCA has provisions for what employers of reportable workers must do. At each reference to a reportable worker, the IRCA-specific definition of the term can be accessed.

Other common subheadings included in most subject areas are "Who Must Comply," "Em-

Welcome to MILAW
F1=Help F3=Quit F4=Forms F5=Source F6=Contact
Included Topics Menu
As discussed in the HELP screen (available by pressing F1), place the cursor on the selection you desire and then press the Enter Key.

Descriptions of Included Topics
IRCA
H-2A
Migrant Labor Camps
Field Sanitation
VOSH
MSPA
Print TOP*TOP

Figure 1. MILAW's opening menu

Welcome to MILAW
F1=Help F3=Quit F4=Forms F5=Source F6=Contact
VOSH
Introduction

A goal of the Virginia Occupational Safety and Health Program (VOSH) is to furnish employees with a safe workplace and to work free from recognized hazards that are likely to cause death or serious physical harm.

Agricultural employers are not specifically exempt from VOSH regulations. The only farmers exempt from VOSH regulations are

1. Self-employed persons who have no employees at all.
2. Farms which employ only immediate family members.

Print VOSH * VOSH-AAAA

Figure 2. Opening menu in VOSH section

ployers Must," or "How to Comply," "Exemptions," "Penalties," and "Reporting and Record Keeping."

The hypertext software was used to tie the subject areas, the subheadings, and all the material together. These ties are illustrated in the following example. In figure 4, the subject heading is IRCA, and the bolded terms to the right are the IRCA subheadings. In the lower sections of the figure, the words contained in boxes are the subheadings repeated, and the bracketed words are all buttons. The arrows refer to the section of text that the particular button accesses.

The example takes the user into the "Employers Must" subheading of IRCA. This path leads to a list of requirements, such as "Have Employees fill out [Form] I-9," etc. These are items that an employer must do in order to comply. For more information, the user might then place the cursor on "[Form] I-9" and be presented with a description of the form and its location in the accompanying *Forms Book*. Alternatively, the user might wish to check the identity and eligibility of an employee. By placing the cursor on the "[Identity and Eligibility]" button, the user enters the subheading "Documents for Verification," which contains its own subheadings, instructions, and access to terms. If the user needs to know the responsibilities with re-

Welcome to MILAW
F1=Help F3=Quit F4=Forms F5=Source F6=Contact
VOSH

	General
VOSH-AAAA	Introduction
VOSH-BAAA	Work Site Inspections
VOSH-CAAA	Employer Record Requirements
VOSH-DAAA	Employee Requirements and Rights
	Specific
VOSH-FAAA	Roll-Over Protective Structures
VOSH-GAAA	Machine Guards and Shields
VOSH-HAAA	Employee Training - Guards and Shields
VOSH-IAAA	Field Sanitation

Print VOSH * VOSH

Figure 3. MILAW screen containing the introduction to VOSH

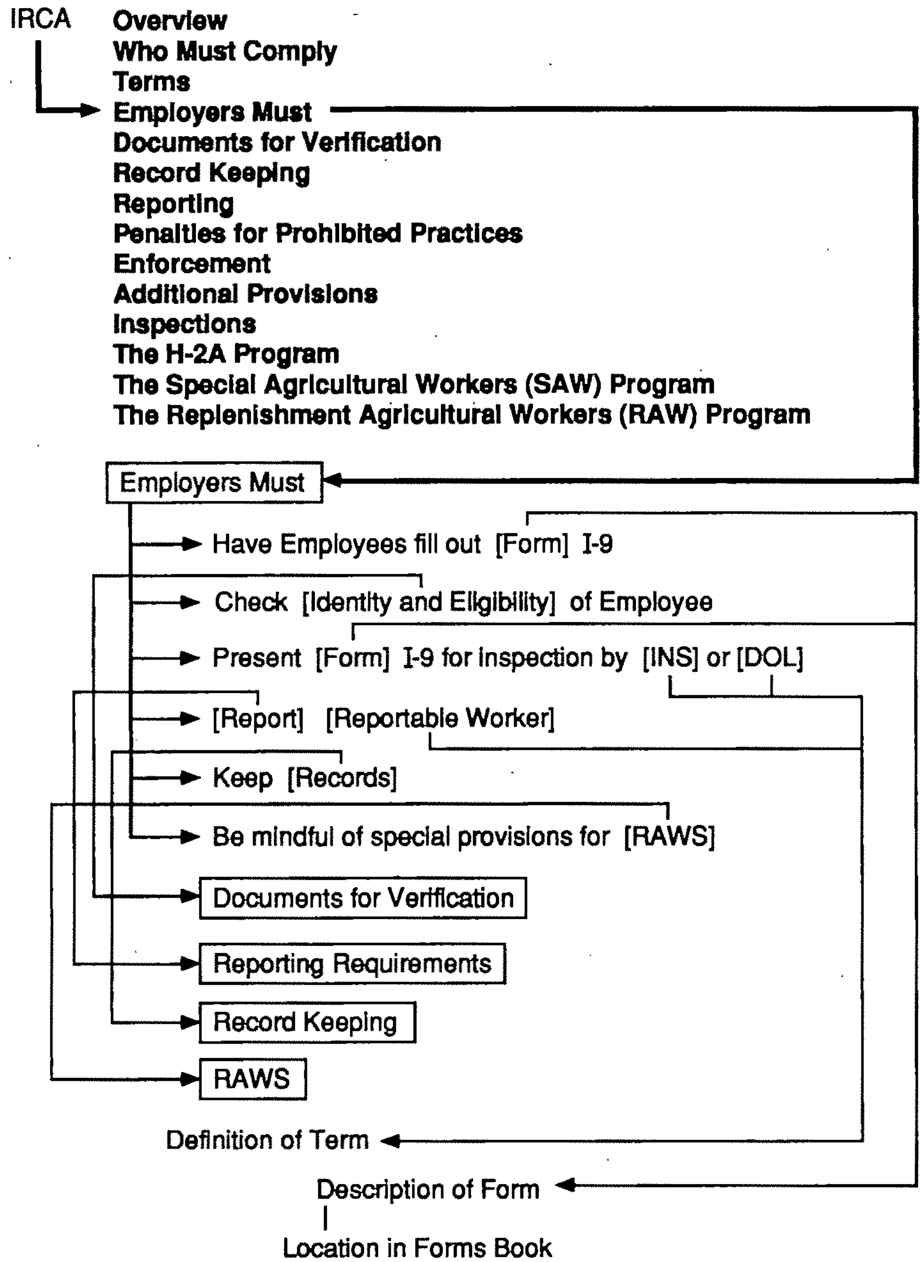


Figure 4. Flow of logic within IRCA's "Employers Must" subheading

gard to reportable workers, either the definition of the term "reportable worker" or the subheading "reporting requirements" can be accessed.

The MILAW Extension Program

As the previous examples made clear, hypertext can be a powerful tool to organize and provide access to complex sets of interrelated regulations. The hard disk storage of the computer provides the reference material, and the software ties it together and provides access. Hence, the compromise between detail and ease of use.

MILAW provides efficient organization of, and access to, the relevant laws and their interpretations. Because the program is basically a text catalog, some understanding of the regulations is necessary to make the best use of the program. This understanding is developed

through continued use of the system, but people who rarely use it and who are not familiar with the breadth of the laws may miss large parts of applicable text or spend inordinate amounts of time exhaustively searching the program for applicable sections.

In addition to concerns about understanding the content, the ability to update the program was important. As legislation and court interpretations evolve, updates are necessary, so the ability to contact users is critical. Further, because of the relatively small numbers of farmers who have access to computers, widespread use on farms was precluded.[5]

These problems were minimized by designing MILAW to be used as a reference tool in extension and job service offices. These users all had computers and access to modems to facilitate electronic updating. In addition, they receive intermittant training on MILAW legislation. Thus, the end users are easily accounted for and reasonably familiar with the law. In this way, MILAW complements other end-user-based information systems, like the manuals described earlier. These manuals are best used to provide general information about the regulations directly to farmers, and MILAW can supplement them to produce a package of steps needed to comply with the laws. The *Forms Book* assists in this process. The extension agent can use MILAW as a reference tool to respond to specific requests for detailed information or produce customized information packages for farmers.[6]

Delivery and Evaluation

MILAW was delivered to seventy-eight extension agents and fifty Virginia Employment Commission agents in early June 1990. There were brief demonstrations of the program conducted at three sites around the state. Reaction to MILAW during the presentation was favorable. The most common reaction was that the program's ease of use made the training unnecessary.

Initial evaluation of the program effectiveness was mostly anecdotal. The individual who normally answers farm labor questions for Cooperative Extension reported a sharp decline in the number of information requests. The information coordinator for the VEC reported a similar decline. Other agencies in the state (the Departments of Labor and Health) requested copies for their field agents. Finally, two other states requested a version specific to their state. The program is easily adapted to other states.

In order to measure the effectiveness of MILAW and investigate alternative avenues for future development, a questionnaire was mailed to 175 recipients of the software. There were 104 respondents, 36% of whom participated in the training session. Forty-two percent of respondents reported having used MILAW in the previous two months; 10% used the program once, 10% used it twice and 21% used MILAW three or more times. The rate of use implied by these numbers might understate use throughout the year; the survey was conducted in November, and the prior two months represent the tail end of the growing season. MILAW users tend to work with tobacco, vegetable, and fruit growers, who use the most labor of Virginia farmers.[7]

The most surprising finding of the survey came during the evaluation of the sections of MILAW most frequently used. The program was promoted as a tool for understanding regulations governing the use of migrant and seasonal labor; however, the most frequently used subject area was worker's compensation (31% of the users reported worker's compensation as their first area of use). The next most common use was the section on the H2-A program (21%), and the sections on child labor, minimum wages, and migrant labor camps (14% each). Interestingly, none of the program users listed the sections on IRCA, MSPA, and OSHA as their most frequent area of use.

Table 1 shows a summary of the user responses broken down by frequency of use. Time saved refers to the time (in hours) saved in the previous month by having access to MILAW. MILAW saves an average of .9 hours per month for its users. During the next growing season

[5] Willimack estimated that fewer than 3% of U.S. farmers used computers for record keeping. While they may understate the total amount of users (see Batte, Jones, and Schnitkey for a discussion of this), a very small percentage of potential MILAW beneficiaries in Virginia probably have access to computers. These new hirers of labor are generally smaller operations than others. In addition, those farmers with access to this technology are most likely to be more educated and already aware of this legislation.

[6] MILAW thus conforms with many of the conditions that the literature says are necessary for computers to have an impact in agricultural extension. It provides software to agents which can be used with minimal training, as well as information which can be used in extension programs (La Ferney, Levins). It also improves the productivity of agents involved in extension programs (Tinsley), as the evaluation of the program makes clear.

[7] Users were defined as people who had used the program at least once in the two months prior to the survey.

Table 1. MILAW Evaluations by Frequency of Program Use

	All Respondents	MILAW Users
Time saved (hrs)		.9
Willingness	70.3	85.2
Percent answered	62	66
Prior source		
Agencies	51.5	28.1
Publications	31.8	56.3
People	16.7	15.6
Average rating		
1 (best)–4 (worst)		
Ease of use	1.7	1.7
Comprehensiveness	2.0	2.0
Report generation	2.0	2.1
Overall	1.8	1.8

Note: MILAW users were distinguished from all respondents based on program use in the prior two months (see fn. 7). Thus, the question on time saved in the previous month is not applicable. Forty-two percent of the nonusers provided responses to the questions related to MILAW's effectiveness. These responses are included for completeness.

this time should increase. Willingness represents the percentage of respondents who said that access to MILAW made them more willing to address labor regulation questions. Prior source refers to the prior source of the information they dispensed: 52% of the respondents received their information from enforcing agencies. Finally, the ratings are average responses on a 1–4 range.

The success of MILAW must be based on two criteria: the amount of time saved and the improved willingness and ability to answer questions. Each criterion implies improved efficiency of extension in responding to client needs. MILAW is doing well under both criteria. It saves its users time, and makes them more willing to respond to these questions. There was little correlation between normal frequency of computer use and use of MILAW; the program's ease of use overcomes many barriers to computer use. MILAW is substituting computer-based information for information normally found in publications or through telephone calls to enforcement agencies. Both of these sources imply more time used in searching for information. As use of the program increases, these benefits will also increase.

In order to provide guidance for further program development, respondents were asked to check a list of potential MILAW improvements. Consistent with widely stated problems of acquiring farm labor in Virginia, the most frequent request (checked on 34% of the questionnaires) was for more information on programs for attaining farm workers. Twenty-eight percent requested more complete background information (such as including the entire federal register text); another 28% wanted improved ease of use by including a menu of keywords with cross linking of access to all the regulations using or refering to the keywords.

Concluding Comments

A key element of successful labor recruitment and retention in agriculture is to understand and comply with the numerous laws and regulations affecting employment in agriculture. The complexity of these laws, the rapidity of change, and the exemptions which agriculture historically enjoyed hinder the ability of farmers to comply.

MILAW is designed to enhance compliance with the laws. It uses a sophisticated software technology to simplify organization of, and access to, the relevant laws. The program, now available at Virginia Cooperative Extension offices and the Virginia Employment Commission is being widely used and appears to save significant time and enhance the ability of agents to provide information related to these regulations.

[Received August 1990; final revision received January 1991.]

References

Batte, Martin T., Eugene Jones, and Gary D. Schnitkey. "Computer Use by Ohio Commercial Farmers." *Amer. J. Agr. Econ.* 72(1990):935–45.

Becker, John, and Robert Parsons. "1989 Conference for Employers of Farm Labor." Dep. Agr. Econ., Pennsylvania State University, 1989.

Coltrane, Robert. *Immigration Reform and Agricultural Labor.* Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Agr. Econ. Rep. No. 510, April 1984.

Covey, C. D. *Handbook of Regulations Affecting Florida Farm Employers and Employees.* Florida Coop. Extens. Serv. Circular No. 801, 1988.

LaFerney, Preston E. "An Administrative Perspective on Microcomputers for Agricultural Research and Education." *S. J. Agr. Econ.* 15(1983):53–56.

Levins, Richard A. "Implications of Microcomputer Technology for Agricultural Economics Programs." *S. J. Agr. Econ.* 15(1983):27–30.

Martin, Philip L., and J. Edward Taylor. "Immigration Reform and California Agriculture a Year Later." *Calif. Agr.* 44(1990):24–28.

Oliviera, Victor, and E. Jane Cox. *The Agricultural Work Force of 1987: A Statistical Profile.* Washington DC:

U.S. Department of Agriculture, Econ. Res. Serv. Agr. Econ. Rep. No. 609, May 1989.

Rosenberg, Howard R., and Daniel L. Egan. *Labor Management Laws in California Agriculture*. Agr. Personnel Manage. Program, California Coop. Extens. Serv., Sep. 1990.

Tinsley, W. A. "Teaching with the Microcomputer: Adoption of a New Technology." *S. J. Agr. Econ.* 15 (1983):57–60.

U.S. Department of Agriculture, Econ. Res. Serv. *Economic Indicators of the Farm Sector: State Financial Summary, 1988*. Washington DC, 1989.

——. *Economic Indicators of the Farm Sector: State Income and Balance Sheet Statistics, 1980*. Washington DC, 1981.

U.S. General Accounting Office (U.S. GAO). *Immigration Reform: Potential Impact on West Coast Farm Labor*. GAO/HRD-89-89, Washington DC, Aug. 1989.

Virginia Statistical Abstract, 1989 Edition. Charlottesville: Center for Public Service, University of Virginia, 1989.

Whitener Smith, Leslie, and Robert Coltrane. *Hired Farmworkers: Background and Trends for the Eighties*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Rural Develop. Res. Rep. No. 32, Sep. 1981.

Willimack, Diane K. "The Financial Record Keeping Practices of U.S. Farm Operators and Their Relationship to Selected Operator Characteristics." Selected paper presented at AAEA annual meeting, Baton Rouge LA, 30 July–2 Aug. 1989.

Food-Pricing Policy in Developing Countries: Further Evidence on Cereal Producer Prices

Daphne S. Taylor and Truman P. Phillips

Recently, two independent studies have produced contradicting evidence regarding the extent of price discrimination in developing countries. The objective of this study is to reexamine the evidence of direct and indirect distortion in cereal producer prices. Nominal protection coefficients for wheat, maize, and rice are calculated for fifty-one developing countries spanning the period 1980–86. Black market exchange rates are used to adjust the nominal protection coefficients to reflect the indirect effect of price interventions through exchange rate policies. The results confirm the conventional wisdom that, although developing countries tend to protect domestic cereal producers, taxation caused by overvaluation of official exchange rates exceeds any direct price protection offered domestic producers.

Key words: exchange rate bias, price distortion, producer prices.

Numerous studies have shown that price discrimination against agricultural producers is common in many developing countries (Bale and Lutz, FAO 1987, Mergos, Peterson, Schultz, World Bank).[1] It is contended that this discrimination has led to agricultural stagnation. Hence, recent policy reform recommendations suggest the removal or at least reduction of price discrimination through exchange rate adjustments, reduction of food subsidies, and increase in agricultural output prices. Such policy reform recommendations are currently being implemented through the World Bank and International Monetary Fund's structural adjustment lending programs (International Monetary Fund 1986).

More recently, two independent studies (Byerlee and Sain; Krueger, Schiff, and Valdes) have produced contradicting evidence regarding the extent of price discrimination against agricultural producers in developing countries. Specifically, the Byerlee and Sain study, which examines the evidence of discrimination in wheat prices for thirty-one developing countries for the period 1980–82, questions the universality of producer price distortions and the emphasis on [raising producer prices as a key element of] policy reform.[2] In contrast, the Krueger, Schiff, and Valdes study, which includes an examination of discrimination in wheat, rice, and maize prices for eighteen countries for the period 1980–84, supports the contention that producer price distortions exist and the need for policy reform.

The objective of this study is to reexamine the evidence of direct and indirect distortion in cereal producer prices. Three cereal commodities in fifty-one countries are examined for the period spanning 1980–86. The sample represents 97% of the wheat produced in developing countries, 97% of the maize, and 86% of the rice. Regionally, the sample includes twenty-one African countries, fourteen Asian countries, and sixteen Latin American countries which were grouped by commodity into four trading categories: net importers, aid recipients, net exporters, and self-sufficient producing countries.

Daphne Taylor is an associate of the Centre for Food Security, University of Guelph; Truman Phillips is a professor in the Department of Agricultural Economics and Business and director of the Centre for Food Security, University of Guelph.

The authors are grateful to Derek Byerlee, director of the economics program at CIMMYT, for his thoughtful commentary and assistance with earlier drafts of this paper.

[1] The time period of analysis in these studies range from the late 1960s to the late 1970s.

[2] Alternatively, they suggest that, for countries experiencing low agricultural productivity, a better policy would be the development of technologies appropriate to farmers in support of input delivery and extension systems.

Methodology

By far the simplest measure of price distortion is the nominal protection coefficient (NPC). Although nominal protection coefficients measure only the deviation of domestic prices relative to world prices, the conclusions drawn regarding the policy environment facing agricultural production activities are essentially the same as those drawn from more robust calculations (Scandizzo and Bruce, Gotsch and Brown).[3] For the purposes of this study, nominal protection coefficients were considered sufficient to examine the evidence of price discrimination in producer prices across developing countries.

NPCs were calculated in this study as follows:

$$NPC = \frac{P_i^d + t^d}{P_i^w + t^w},$$

where P_i^d is the domestic farm gate producer price of output i, P_i^w is the border price of output i in local currency at official exchange rates, and t^d and t^w are the transport costs associated with moving output i from the farmgate and border to a common consumption location, respectively. The resulting NPC represents the magnitude of direct intervention in domestic price determination by measuring the extent to which the domestic prices deviate from the border prices facing the country. Indirect interventions brought about by exchange rates policies were measured by an adjusted NPC which took into account biased official exchange rates.

Data for Calculating NPCs

Because NPC estimates are sensitive to underlying data choices, the following discussion briefly describes the data and procedures used in the calculation of producer prices, border prices, and transportation costs.

Producer Prices

Farmgate prices for NPCs are usually taken from the Food and Agriculture Organization (FAO) Producer Price Series (Peterson, FAO 1987). Unfortunately, the FAO Producer Price Series are available for only a limited number of countries, often are not up to date, and on occasion represent official prices as reported by the government as opposed to actual farmgate prices received by farmers. An alternative to this series is farmgate producer survey prices collected by international agricultural research institutions (Byerlee and Sain). The International Maize and Wheat Improvement Centre (CIMMYT) collects data on farmgate prices which represent actual market prices at a low point in the seasonal cycle in major producing regions and are usually the most up-to-date series available.[4] This series, however, is available only in alternative years for wheat and maize. For example, CIMMYT collected farmgate prices for maize for the years 1980/81, 1983/84 and 1985/86. They collected farmgate prices for wheat for the years 1980/81, 1981/82 and 1984/85. The International Rice Research Institute (IRRI) also compiles data on farmgate harvest prices for rice but only for a very limited number of Asian countries (Bangladesh, India, Indonesia, Korea, Philippines, and Thailand).[5] To construct as broad a sample as possible for this study, the FAO series was used to supplement CIMMYT and IRRI data for those years and countries for which data were not available.[6]

Border Prices

Border prices may be calculated using an "undistorted" international price adjusted for a premium reflecting differential freight rates as in Byerlee and Sain or by using actual CIF and FOB border prices (i.e., trade unit values) reported for individual countries. In this study trade unit values were used to reflect the border prices facing each country for each commodity and year.[7]

[3] Alternative methods, such as the effective protection coefficient, effective subsidy coefficient, producer subsidy equivalent, resource cost ratio, and domestic resource cost, provide more detail on the effects of price distortion on agricultural production.

[4] CIMMYT collects wheat and maize producer prices through questionnaires which are sent to agricultural researchers and extension workers working in the country and who have frequent farmer contact in major cereal-producing regions. The questionnaire requests information on the post-harvest price, the price of nitrogenous fertilizer, and the daily wage rate for unskilled labor for the most recent production season (CIMMYT).

[5] Unlike CIMMYT, IRRI does not collect primary data on producer farmgate prices but compiles and publishes data from government and other sources in their publication *World Rice Statistics*.

[6] FAO data was the principle source for maize prices in 1981/82 and 1982/83, wheat prices in 1982/83, and rice prices in 1980/81, 1981/82, 1982/83.

[7] Yearly trade unit values were calculated by dividing the total value of imports and exports by their total quantities as reported in FAO statistics.

It is argued that trade unit values more accurately reflect the opportunity costs facing domestic producers because they are the prices with which domestic producers must complete (Scandizzo and Bruce).[8]

Internal Transportation Costs

Internal transportation costs were used to adjust both border and farmgate prices to each country's major consumption or market center, as done by Byerlee and Sain. This center was assumed to be the largest, most populated city in each country. For importing countries, the cost of transporting produce from the production region to the consumption point was added to the farmgate price, and the cost of transporting produce from the port to the consumption point was added to the border price. For exporting countries, the cost of transporting produce from the production region to the port was added to the farmgate price. Internal transportation distances and road conditions were determined individually for each country and commodity in this study using Bartholomew maps and transportation costs by truck or wagon estimated at US \$.07 to US \$.10 per tonne per kilometer for paved roads, \$.15 for gravel roads, and \$.20 to \$.25 for dirt tracks. For mountainous regions these estimates were adjusted upward by 20%.[9]

Together, these data were used to calculate NPCs. The resulting values are discussed in the following sections.

Results on Direct Price Intervention

A total of 310 NPCs were calculated; 152 for maize, 85 for wheat, and 73 for rice for fifty-one countries spanning the period 1980–86. For presentation and analytical purposes, NPCs were averaged by country and commodity for the period 1980–86 (see appendix). The sample includes twenty-one African countries, fourteen Asian countries, and sixteen Latin American countries.

Because the study by Krueger, Schiff, and Valdes noted that, on average, food imports are subsidized while exports are generally taxed, each country by commodity in this study was classified as a net importer, a net exporter, a food-aid-recipient importer, or a self-sufficient producer over the period 1980–86. Self-sufficient countries were those countries which shifted between net exporting and net importing positions within the time period under examination. Aid recipient countries were identified as net importing countries where food aid receipts made up more than 50% on average of the total imports of the commodity.

To reduce the possibility that countries are classified as having an environment of protection or discrimination when in fact they do not, NPCs within the range of .85 to 1.15 are considered to be free of price intervention. NPCs less than .85 represent an environment of taxation while NPCs greater than 1.15 represent an environment of protection. This approach was also taken by Byerlee and Sain.

Table 1 summarizes the results in terms of average NPC and standard deviation for each commodity and trade grouping.[10] Of the seven groups, only two appear to have direct taxation: rice producers (.83) and net exporting countries (.84). Although a relationship between net exporters and rice producing countries is apparent, in fact less than half the NPCs calculated for rice were identified as net exporters. At the other extreme, direct protection is indicated for three groups: maize (1.30), wheat (1.19), and net importers (1.42). The average NPCs for the remaining two groups indicate neutral policy environments: aid recipients (.99) and self-sufficient producers (1.07). These results suggest that, on average, direct producer price discrimination is evident in only rice and net exported commodities. Within trading categories, maize is protected at a higher rate than wheat, while rice generally receives the least price protection. These results are consistent with the results found by both Byerlee and Sain and Krueger, Schiff, and Valdes.

While, all three studies conclude that direct domestic cereal price discrimination is not widespread, it is widely acknowledged that exchange rate policies significantly affect trading patterns and opportunities. Exchange rate policies can act either as an indirect tax or as a subsidy on agricultural prices in developing countries (World

---

[8] Years when countries were net importers, CIF values were used. Years when countries were net exporter, FOB values were used. For those countries and years where neither imports nor exports were reported in the FAO statistics, a border price was taken from a neighboring country that best reflected the border price facing that country if it had imported.

[9] These estimates were provided by Charles Van Dervoort, Department of Transportation, Washington, D.C., 8 November 1988. Van Dervoort is a member of the Interagency Task Force on the African Emergency Transportation Team.

[10] Regional NPC averages were not found to be statistically different and therefore are not discussed here. They may be found however in the appendix.

Table 1 Summary of Unadjusted NPC Results by Commodity and Trade Groupings

Groupings	Maize	Wheat	Rice	Average NPC	Standard Deviation	Number of Observations
Net importer	1.64	1.43	1.14	1.42	.57	110
Aid recipient	1.14	.97	.66	.99	.46	95
Net exporter	1.13	.67	.62	.84	.40	35
Self-sufficient	1.21	.97	.59	1.07	.49	64
Average NPC	1.30	1.19	.83	1.15		
Standard deviation	.62	.46	.37		.55	
Number of observations	147	85	72			304

Note: This summary excludes Ghana's NPC for maize and Venezuela's NPC for rice.

Bank, FAO 1987, Peterson, Schultz). To determine if exchange rate policies provide indirect price distortions, NPCs were adjusted for biases in official exchange rates.

Exchange Rate Bias

Two methods are commonly used to account for exchange rate bias. The most common method is to adjust official exchange rates to reflect the differential inflation rate between domestic and import prices (Byerlee and Sain, FAO 1987). However, this type of correction ignores factors other than inflation differentials that lead to exchange rate distortions. For example, Byerlee and Sain note that in a country such as India, the inflation method indicates an undervalued exchange rate, but high tariff protection and import controls relative to export subsidies would suggest significant overvaluation.

The second method is to calculate shadow or equilibrium exchange rates. Krueger, Schiff, and Valdes define equilibrium exchange rates as the real exchange rate necessary to keep current accounts sustainable within a country if all quantitative and tariff protection against imports and intervention affecting exports were removed. This involves the estimation of the equivalent tariff on import protection, foreign exchange demand, and supply elasticities and comparison with the actual real exchange rate to estimate the amount of change in the real exchange rate needed to yield a sustainable current account level. Such procedures require substantial research resources and in-depth study within each country, which limits the timeliness of the estimates.

This study introduces a simpler approach. This approach is to measure exchange rate bias as the ratio of black market exchange rates (Cowitt) to official exchange rates (IMF). Although black market rates may reflect a risk premium on the exchange owing to the illegal nature of the transaction, they produced results similar to those found by Krueger, Schiff, and Valdes but were easier and less costly to calculate than shadow exchange rates.[11] The use of black market adjustments, however, did lead to some important differences from the Byerlee and Sain study (Taylor).

Results on Indirect Price Intervention

Adjustments for exchange rate bias were made to the 310 original NPCs by multiplying each NPC by the ratio of the black market exchange rate to the official exchange rate for that year. The results are summarized in table 2.

In sharp contrast to table 1, table 2 shows that the average adjusted NPC is less than .85 in five of the seven groups and is less than 1.15 for the remaining two groups. Those groups that have an environment of taxation are wheat (.76), rice (.62), aid recipients (.68), net exporters (.58), and self-sufficient producers (.82). Maize (.93) and net importers (1.01) have neutral policy environments.

By trading group, producers in self-sufficient countries and aid recipient countries face taxation because of exchange rate distortions, whereas indirect taxation merely offsets the advantages of direct subsidies in net importing countries and increases the taxation within net exporting countries.

These results suggest that the classification of countries by their trading posture is important. For example, when the indirect effects of exchange rate bias are not considered, countries

[11] Cowitt black market rates were also used in a recent World Bank study examining global trends in real exchange rates (Wood).

Table 2. Summary of NPC Results Adjusted for Exchange Rate Bias by Commodity and Trade Groupings

Groupings	Maize	Wheat	Rice	Average NPC	Standard Deviation	Number of Observations
Net importer	1.23	.95	.82	1.01	.54	110
Aid recipient	.80	.65	.44	.68	.41	100
Net exporter	.72	.40	.49	.58	.29	35
Self-sufficient	.90	.76	.54	.82	.38	64
Average NPC	.93	.79	.62	.81		
Standard deviation	.54	.39	.32		.47	
Number of observations	152	85	72			309

Note: This summary excludes Venezuela's Adjusted NPC for rice.

which receive substantial volumes of food aid illustrate neutral policy environments, whereas net importing countries illustrate protective policy environments (table 1). When the indirect effects of exchange rate bias are considered (table 2) aid recipient countries illustrate significant taxation toward domestic producers (the average NPC is only slightly higher than that observed in net exporting countries), whereas exchange rate policies merely neutralize the direct protection observed in net importing countries.

A comparison of the results contained in table 2 with those contained in table 1 provides strong evidence that indirect price discrimination owing to distorted exchange rate policies is widespread in developing countries. In most cases, taxation from indirect intervention though exchange rate distortion exacerbates taxation caused by direct pricing policies and negates any protection offered producers though favorable direct pricing policies. This result is consistent with the results of the Krueger, Schiff, and Valdes study which found that imported commodities (mostly cereals) were taxed at a rate of approximately 7% when direct and indirect effects were considered. This is contrary to the results of the Byerlee and Sain study, which did not find strong evidence of exchange rate distortion.[12]

Concluding Comments

The results of this study confirm many of the basic premises regarding trading patterns and pricing policies. Exporting countries use agricultural taxation to generate needed revenue, and importing countries, in general, offer production incentives to domestic agricultural producers in the hope of reducing import dependency (Krueger, Schiff, and Valdes). The extent of direct and indirect price discrimination in developing countries suggests that, although developing countries tend to protect domestic cereal producers, taxation caused by overvaluation of official exchange rates exceeds any direct price protection offered domestic producers. The tendency to provide direct price protection to cereal producers was strongest for maize producers and weakest for rice producers. However, all cereal producers were found to compete against cheaper cereal imports owing to overvalued official exchange rates. This result is consistent with individual country studies reported by Krueger, Schiff, and Valdes but contradicts the conclusions for wheat drawn by Byerlee and Sain.

The results of this study go beyond those of previous studies by examining a broader and larger sample of countries and by examining the impacts of pricing policies by commodity, trading, and regional groupings. In particular, this study has revealed that divergent price policy environments exist between net importing and food aid recipient countries. A strong negative pricing bias against domestic producers was observed in aid receiving countries, whereas a strong protective bias was revealed in net importing countries. This result has previously been overlooked because most studies assume a homogenous group of net importing countries.

The implication for policy reform is that the common dual recommendations of realigning exchange rates and increasing agricultural producer prices may be inappropriate. If exchange

[12] The average adjusted NPC for wheat-producing countries in the Byerlee and Sain study was 1.02. For those same countries and years, the adjusted NPC in this study was .83.

rate reforms are achieved, most of the countries covered in this study will appear to have direct price protection policies prevail, particularly for maize producers. Thus, recommendations for increased agricultural prices may not be necessary if exchange rate reforms are successful. In fact, if the objective is to achieve efficiencies in resource allocation, policy makers may wish to lessen direct support programs, once exchange rates have been devalued.

Finally, the use of published black market exchange rates could make tracking price distortions a much more routine and less demanding undertaking than is suggested by Krueger, Schiff, and Valdes.

[Received August 1989; final revision received January 1991.]

References

Bale, M. D., and E. Lutz. *Price Distortions in Agriculture and Their Effects: An International Comparison.* Washington DC: World Bank Staff Work. Pap. No. 359, 1979.

Byerlee, D., and G. Sain. "Food Pricing Policy in Developing Countries: Bias against Agriculture or for Urban Consumers?" *Amer. J. Agr. Econ.* 68(1986):961–69.

CIMMYT. *World Maize Facts and Trends CIMMYT Report One: Analysis of Changes in Production, Consumption, Trade and Prices over the Last Two Decades.* Mexico, D.F., 1981.

——. *1984 CIMMYT Maize Facts and Trends Report Two: An Analysis of Changes in Third World Food and Feed Uses of Maize.* Mexico, D.F., 1985.

——. *1986 CIMMYT World Maize Facts and Trends: The Economics of Commercial Maize Seed Production in Developing Countries.* Mexico, D.F., 1987.

——. *1985 CIMMYT World Wheat Facts and Trends Report Three: A Discussion of Selected Wheat Marketing and Pricing Issues in Developing Countries,* Mexico, D.F., 1986.

——. *1983 World Wheat Facts and Trends Report Two: An Analysis of Rapidly Rising Third World Consumption and Imports of Wheat.* Mexico, D.F., 1984.

——. *World Wheat Facts and Trends CIMMYT Report Two: Analysis of Changes in Production, Consumption, Trade and Prices over the Last Two Decades.* Mexico, D.F., 1981.

Cowitt, Philp P., ed. *World Currency Yearbook, 1985.* Brooklyn NY: International Currency Analysis, 1986.

FAO. *Agricultural Price Policies: Issues and Proposals.* Rome: FAO Econ. and Soc. Develop. Ser. No. 42, 1987.

——. *FAO Trade Yearbook.* Rome, various issues.

Gotsch, C., and G. Brown. *Prices, Taxes and Subsidies in Pakistan Agriculture, 1960–1976.* Washington DC: World Bank Staff Work. Pap. No. 387, 1980.

International Monetary Fund. *Fund-Supported Programs, Fiscal Policy, and Income Distribution.* Occas. Pap. No. 46, Washington DC, 1986.

——. *International Financial Statistics, Yearbook.* Washington DC, various issues.

IRRI. *World Rice Statistics 1985.* Manila, Philippines, 1985.

Krueger, A., M. Schiff, A. Valdes. "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economy-Wide Policies." *World Bank Econ. Rev.* 2(1988):255–71.

Mergos, G. "Relative Distortions of Agricultural Incentives: A Cross-Country Analysis for Wheat, Rice and Maize." *Agr. Admin. and Extens.* 24(1987):195–211.

Peterson, W. L. "International Farm Prices and the Social Cost of Cheap Food Policies." *Amer. J. Agr. Econ.* 61(1979):12–21.

Scandizzo, P. L., and Colin Bruce. *Methodologies for Measuring Agriculture Price Intervention Effects.* Washington DC: World Bank Staff Work. Pap. No. 394, 1980.

Schultz, T. W. "On Economics and Politics of Agriculture." *Distortions of Agricultural Incentives,* ed. T. W. Schultz. Bloomington: Indiana University Press, 1978.

Taylor, Daphne S. *A Cross-Country Analysis of Food Grain Price Differentials.* M.Sc. thesis, University of Guelph, 1989.

Wood, A. *Global Trends in Real Exchange Rates 1960 to 1984.* Washington DC: World Bank Disc. Pap. No. 35, 1988.

World Bank. *World Development Report 1982.* Washington DC, 1982.

Appendix

Average NPCs Country and Commodity Spanning 1980–86

West Asia and North Africa

	Unadjusted NPC			NPC Adjusted for Exchange Rate Bias		
Country	Maize	Wheat	Rice	Maize	Wheat	Rice
Algeria		1.57			.36	
Egypt	.82	.44	.40	.49	.33	.30
Morocco	2.25	1.23		2.04	1.07	
Tunisia		.91			.76	
Iran		2.55			.38	
Iraq		1.14			.28	
Jordan		1.03			.96	
Syria	2.29	1.49		1.47	.87	
Turkey	1.14	.92	1.13	.85	.69	.82
Average	1.63	1.25	.76	1.21	.63	.56

Sub-Saharan Africa

	Unadjusted NPC			NPC Adjusted for Exchange Rate Bias		
Country	Maize	Wheat	Rice	Maize	Wheat	Rice
Benin	1.08			.91		
Burkina Faso	.98			.83		
Cameroon	.72	.91	1.13	.72	.86	1.06
Ethiopia	.65	.88		.41	.56	
Ghana	24.34			1.02		
Ivory Coast	1.19		.75	1.14		.71
Kenya	1.28	.96	.44	1.08	.73	.34
Madagascar	1.36			1.06		
Malawi	.78		.30	.47		.16
Mozambique	1.01			.25		
Niger	2.81		.51	2.37		.48
Senegal	1.47		.77	1.35		.71
Sudan	.72	1.59		.38	.85	
Tanzania	1.60	1.03	.59	.47	.30	.19
Zaire	1.49			.52		
Zambia	.67	1.08	.76	.45	.72	.50
Zimbabwe	.83	.65	___	.41	.30	___
Average	2.53	1.02	.66	.81	.62	.52
(ex. Ghana)	1.17					

Far East Asia

	Unadjusted NPC			NPC Adjusted for Exchange Rate Bias		
Country	Maize	Wheat	Rice	Maize	Wheat	Rice
Bangladesh	.65	1.31	.86	.35	.74	.47
China	2.36	1.36	1.17	1.91	1.10	.91
India	1.24	1.00	.45	1.07	.87	.41
Indonesia	1.23		.60	1.14		.57
Korea	2.65	2.30	1.93	2.43	2.19	1.77
Nepal	.76	.82		.63	.70	
Pakistan	1.13	.77	.57	.91	.56	.41
Philippines	1.56		.71	1.37		.64
Thailand	1.08	___	.50	1.11	___	.49
Average	1.41	1.26	.85	1.21	1.03	.71

Latin America

Country	Unadjusted NPC			NPC Adjusted for Exchange Rate Bias		
	Maize	Wheat	Rice	Maize	Wheat	Rice
Argentina	.66	.67		.41	.40	
Bolivia	.65			.33		
Brazil	1.46	1.43	1.06	1.10	1.19	.61
Chile	.90	1.16		.66	.94	
Colombia	1.45	.95	.78	1.23	.87	.67
Dominican Rep.	1.19		.82	.79		.39
Ecuador	2.19	1.33	.99	1.26	.89	.68
El Salvador	.99			.40		
Guatemala	.72			.34		
Haiti	1.11			1.11		
Honduras	.53			.53		
Mexico	2.03	1.52	1.28	1.23	1.15	.81
Paraguay	1.73		1.51	.62		.65
Peru	2.96	1.85	.84	2.09	1.46	.67
Uruguay	1.03	.77		.82	.56	
Venezuela	1.26	—	3.88	.47	—	3.58
Average	1.30	1.21	1.39	.84	.93	1.01
(ex. Venezuela)			1.04			.64

An Analytical Model of Farmers' Demand for Replacement Seed

Paul W. Heisey and John P. Brennan

Seed replacement choices differ from decisions about other inputs, such as fertilizer, because the farmer can reproduce seed. Assumptions about rates of improvement in yield potential and depreciation of retained seed are combined with behavioral assumptions and price and technical information to develop a model predicting the number of years before a farmer will buy new seed. Parameter estimates for wheat in Pakistan are fed into the model and results compared with observed replacement times. Time horizon strongly conditions effects of model parameters. To speed varietal change, better information for farmers is likely to be preferred to seed subsidies.

Key words: Pakistan, seed replacement, time horizon, varietal change, wheat.

The purchase of new seed of a variety that a farmer is already growing, varietal replacement in general, and varietal choice during periods of rapid technological change are examples of seed replacement choices. A seed replacement choice differs from decisions about other inputs, such as fertilizer or labor, in that seeds can be reproduced for the next crop season. Benefits from the purchase of new seed can continue for several years, and purchased seed is a self-sustaining input, although it is subject to depreciation. Replacement seed is, therefore, in some ways analogous to a capital item rather than a variable input.

Agricultural economists, in general, have considered only the analysis of varietal choice with rapid technological change. Theoretical (Nowshirvani) and empirical (Herath, Hardaker, and Anderson; Gafsi and Roe) studies of varietal choice tend to model the farmer's decision as a single period portfolio allocation of land between modern and traditional varieties. Thus, the attributes of interest are yield, moments of the yield distribution, and occasionally other varietal characteristics. Other approaches to analyzing farmers' choice of seed technology emphasize how a related input (fertilizer, tubewells) affects the level and riskiness of return (Feder 1980, 1982). Prices, risk, the lumpiness of the associated inputs, and possible credit constraints determine the portfolio choice over time in these models. In none of these approaches is the more general case of demand for replacement seed explicitly recognized.

This paper proposes an analytical model of the demand for replacement seed. The model describes the factors that induce a farmer to replace seed and the optimal frequency of new seed purchase given myopic and infinite time horizons. The model is applied to wheat seed demand in Pakistan. Conclusions, limitations, and possible extensions of the model are also considered.

Model of Seed Replacement

The decision to replace seed without changing variety is caused by deterioration in production potential of the seed retained from the farmer's grain crop. Genetic deterioration is particularly evident for hybrids or for cross-pollinating crops like open-pollinated maize varieties, in which yield potential may diminish from one generation to the next. The seed of self-pollinating crops such as wheat can also deteriorate through intermixture with seed of other varieties or species or loss of germination potential during storage.

Paul W. Heisey and John P. Brennan are, respectively, Regional Economist, Malawi, with the Economics Program, International Maize and Wheat Improvement Center (CIMMYT), and Senior Economist, Agricultural Research Institute, Wagga Wagga, Australia. The paper was written while Brennan was a visiting research fellow, Mexico, with the CIMMYT Economics Program.

The views in this paper are those of the authors and are not to be attributed to CIMMYT.

The interest and support of the Pakistan Agricultural Research Council in several larger studies of the economics of wheat production, out of which this work grew, are gratefully acknowledged.

The authors also wish to acknowledge the contributions of Derek Byerlee, Jesse Dubin, Greg Edmeades, Peter Hobbs, Jim Longmire, Matt McMahon, Michael Morris, Mitch Renkow, Melinda Smale, Greg Traxler, and two anonymous *Journal* referees in the development of this paper.

Yield deterioration of the old variety may also affect the farmer's decision to replace seed for the purposes of varietal change. In addition to the reasons just specified, a breakdown in disease or pest resistance of the older variety may cause varietal replacement. In this case, the maximum yield potential of the older variety has not deteriorated; instead, mutation of the disease pathogen or pest overcomes the resistance formerly conferred by a gene or gene complex in the variety, causing a reduction in expected yield. Finally, varietal change will also be related to the superior yield of the new variety or improvement in other desirable characteristics, or both.

In the model, farmers' utility $u(\pi, t)$ is composed of two attributes; π is net benefits from planting a given variety at t, and t is the number of years since seed has been replaced. Further, $U(\pi, t)$ is assumed separable in π and t, $u(\pi, t) = v(\pi)\phi(t)$, where $v(\pi)$ is a value function and $\phi(t)$ is a discount function (Loewenstein and Prelec). Farmers understand the general pattern of yield deterioration in their own varieties. They are uncertain about the yield potential of replacement varieties, which they learn about over time. In the next section, we state the assumptions regarding the time dimension of the model, yield improvement of the crop, depreciation of farmers' seed, and farmers' uncertainty about potential yields.

Elements of the Basic Model

We assume for convenience that harvest in time t, the time at which benefits are received for that period, coincides with the time when the farmer decides to change varieties or plant retained seed for period $t + 1$. The relevant crop production period is one year, and the possibilities of fallow periods or rotation crops are ignored. The farmer's opportunity cost of using his or her own seed is the grain price p_g (per kilogram, kg). If the farmer buys seed, the price paid is p_s. Assuming equal seed rates of S kilograms per hectare, the per hectare cost of using seed retained from the previous grain harvest is p_gS, while the cost of using new seed is p_sS.

The farmer harvests grain at year end. If he or she plants retained seed, the per hectare yield is Y_c and the associated gross per hectare revenue is p_gY_c. Alternatively, if he or she plants new seed, the per hectare yield is y_n and the associated gross per hectare revenue is p_gY_n.

Base yield (under farmers' management) obtained in the initial year the farmer buys seed of a new variety is denoted as Y_o. The expected yield under farmers' management of a potential replacement variety t years later, from the perspective of the plant breeders who develop it, is Y_{nt}. This can be expressed as

$$(1) \qquad Y_{nt} = (1 + i)^tY_0 = A^tY_0,$$

where $100i\%$ is the annual rate of gains in expected yield through breeding research and $A = 1 + i$. For exposition, i is assumed to be constant. If the farmer buys seed of a new higher yielding variety, then $A > 1$. If he buys new seed of his old variety, or of a new variety with no yield advantage, then $A = 1$.

Similarly, if the expected yield of the farmer's original variety deteriorates at an annual rate of $100j\%$, the projected yield, Y_{ct}, on farms in year t is

$$(2) \qquad Y_{ct} = (1 - j)^tY_0 = B^tY_0,$$

where $B = 1 - j$. If seed quality deterioration occurs, a fixed annual rate of farmer seed deterioration implies absolute losses become less from year to year.

We characterize farmers' uncertainty about the expected yield of potential replacement varieties by assuming farmers require a minimum acceptable marginal rate of return over the crop cycle, $100R\%$, higher than $100r\%$, the opportunity cost of working capital over the cycle (CIMMYT). The minimum acceptable rate of return is used to discount expected differences in profits from using a newer rather than an older variety. The farmer's level of uncertainty decreases the greater the number of years, t, that he or she retains seed. These assumptions are summarized as follows:

$$(3) \qquad R_t = R(t)$$

where

$$R' \leq 0, R'' \geq 0, \text{ and } \lim_{t \to \infty} R(t) = r.$$

Applying a discount rate defined in this way is analogous to applying an efficiency factor to yield. As the farmer accumulates knowledge about the expected yield of the replacement variety through experience, his or her expected yield approaches the actual yield. These assumptions are analogous to those of the passive learning model outlined by Kislev and Shchori-Bachrach. Learning curves of the type specified by Kislev and Shchori-Bachrach could result from Bayesian updating of expected values and vari-

ances if profits are distributed normally (Feder and O'Mara; Lindner, Fischer, and Pardey).

In this paper, R_t is defined implicitly as follows:

$$(4) \qquad (1 + R_t)^t = (1 + R_1)(1 + r)^{t-1}.$$

Thus, R_t satisfies the assumptions listed in (3). In the present construction, the value of $R_1 - r$ could be related to the farmer's general degree of confidence in new varietal development and R' to the speed of learning. The psychology literature sometimes uses specification (4) to characterize actual discounting behavior, and discount rates inferred both experimentally and from actual choices often approximate this pattern (Benzion, Rapoport, and Yagil; Loewenstein and Thaler).

In the development of the model, X_t, X_1, and W are defined as the discount factors associated with R_t, R_1, and r, respectively, for example by $X_t = 1/(1 + R_t)$, and thus from (4)

$$(5) \qquad (X_t)^t = X_1 W^{t-1}.$$

In the model, therefore, farmers maximize $u(\pi, t) = v(\pi)\phi(t)$ where $v(\pi) = \pi$ and $\phi(t) = X_1 W^{t-1}$, $t \geq 1$. Farmers can be viewed as "risk neutral" in the sense that $v(\pi)$ is linear. Decreasing uncertainty with greater experience of a variety is represented by the assumptions concerning the discount function $\phi(t)$.[1]

Myopic Horizon (Minimum Time of Profitable Varietal Replacement)

In the myopic version of the model, the farmer is concerned only with costs and benefits over the crop cycle in which he or she buys new seed.[2] This assumption, often made in "time to adoption" models (Lindner, Fischer, and Pardey), implies the farmer buys new seed in the first year in which he or she expects it is profitable to do so. In this version of the model, π is the difference in profits per hectare between planting new seed and planting seed retained from the previous year's grain crop, and the farmer's utility is

$$(6) \qquad u(\pi,t) = p_g Y_0 (A^t - B^t)X_1 - (p_s S - p_g S).$$

From the year of initial purchase, the number of years until it is profitable for the farmer to buy new seed is T^*, where

$$(7) \qquad T^* = \min t \quad s.t.\ u(\pi,t) \geq 0, \quad t \in Z^+$$

(i.e., t is a positive integer).

Optimal Rate of Replacement with Discounted Costs and Benefits

Alternatively, the model can be specified to represent the stream of net benefits from some initial point of varietal change, rather than the benefits received only in the year of the change as above.

In equilibrium, the farmer changes seed every T years. That is, a new variety is planted at times 0, T, $2T$, $3T$, and so on. Combined with the previous assumption that research increases the crop's yield potential over time, this implies that the farmer's yields follow the pattern shown in figure 1.

Net benefits π in this case consist of gross returns minus seed costs. Benefits from planting at time $\tau = nT + t$ occur at the end of the crop cycle, i.e., at time $nT + t + 1$. We can then show that the expected gross returns per hectare at any time $nT + t + 1$, discounted to $nT + t = 0$, are[3]

$$(8) \qquad DGR_{nT+t+1} = p_g Y_0 A^{nT} B^t X_1^{n+1} W^{n(T-1)+t} \qquad n = 0,1,2, \ldots, t = 0,1,2, \ldots, T-1.$$

By applying the rules for summation of series with multiplicative term less than one, we can demonstrate that the expected total gross returns per hectare at times from $nT + 1$ through $(n + 1)T$ are

$$(9) \qquad p_g Y_0 A^{nT} X_1^{n+1} W^{n(T-1)} \left[\frac{1 - (BW)^T}{1 - BW}\right] \qquad n = 0,1,2, \ldots.$$

Similarly, the expected total discounted gross benefits per hectare over an infinite time hori-

---

[1] A more rigorous approach to observed patterns of time-dependent choices can be found in Loewenstein and Prelec and in Prelec and Loewenstein, who place restrictions on both $v(\pi)$ and $\phi(t)$. Among other characteristics, $-\phi'(t_1)/\phi(t_1) > -\phi'(t_2)/\phi(t_2)$ for all $t_2 > t_1$. In our model $-\phi'(t)/\phi(t)$ is constant for $t > 1$. The phenomenon of greater sensitivity to time delay if it occurs earlier rather than later is accounted for only by an implicit discontinuity in $-\phi'(t)/\phi(t)$ at $t = 1$.

[2] A major private U.S. soybean seed company plans using a myopic model assuming benefits only in the year of seed change, coupled with a very high minimum acceptable marginal rate of return (McMullen).

[3] Details of these and other derivations are available from the authors upon request.

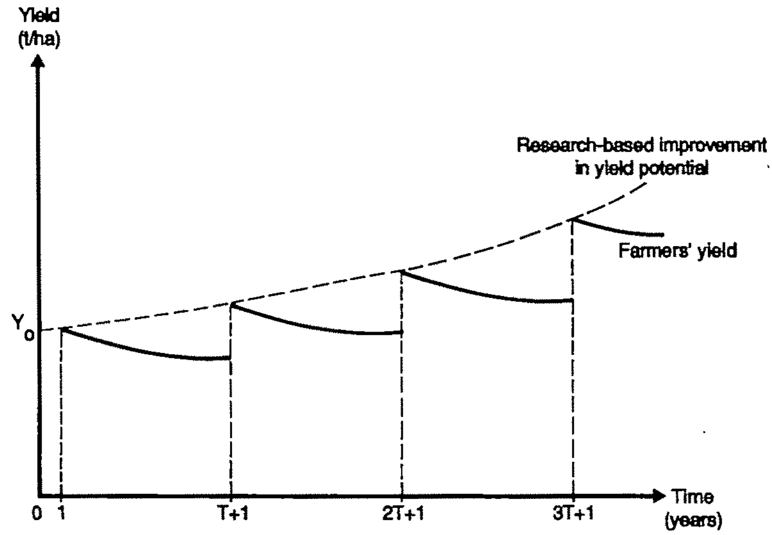


Figure 1. Farmers' yields over time with varietal change every T years.

zon (*TDGB*) can be expressed as

$$(10) \quad TDGB = p_g Y_0 X_1 \left[\frac{1-(BW)^T}{1-BW}\right]\left[\frac{1}{1-Z}\right]$$

when $Z = A^T X_1 W^{T-1}$ is less than one.[4]

Total costs consist of new seed costs at time 0, T, $2T$, ..., and the opportunity costs of retaining some of the harvest as seed in all other years. New seed costs are $p_s S$ per hectare. The total discounted costs per hectare of new seed, *TDCNS*, are

$$(11) \quad TDCNS = p_s S \left[\frac{1}{1-X_1 W^{T-1}}\right].$$

Opportunity costs of retaining grain for seed are $p_g S$ per hectare at times $nT+1, \ldots, (n+1)T-1$ for $n = 0, 1, 2, \ldots$. Total discounted costs per hectare of retained seed, *TDCRS*, are

$$(12) \quad TDCRS = p_g S X_1 \left[\frac{1-W^{T-1}}{1-W}\right]\left[\frac{1}{1-X_1 W^{T-1}}\right].$$

Expected discounted profits per hectare, $ED\pi = \Sigma_{\tau=0}^{\infty} u(\pi, \tau)$, are thus equivalent to

$$(13) \quad ED\pi = TDGB - TDCNS - TDCRS.$$

The optimal rate of varietal replacement, T^{**}, given an infinite time horizon, is the value of T that maximizes (13). First-order conditions for maximizing (13) can be derived, but they are untidy, and numerical methods are required to solve them. Calculating $ED\pi$ for feasible integer values of T and determining T^{**} by inspection, after inserting empirically determined values of the parameters, is simpler.[5]

Discounted net benefits can be plotted against T for various assumptions about parameter values. Figure 2 displays one example based on Pakistan data for wheat. The notable feature of figure 2 is that the discounted expected profit curve increases quickly initially and then flattens. This relative insensitivity of the level of discounted net benefits around the optimum, T^{**}, is shared by a similar problem from elementary capital theory, optimum replacement of an infinite chain of machines. Attempts to determine precise optima may be unwarranted, a feature these time-dependent problems may share with many single-period optimization procedures (Anderson). Given the parameters used to derive figure 2, any varietal replacement period of three years or more will result in discounted expected profits 90% or more of the maximum level. In situations in which it is appropriate to assume rather stable parameters and farmers who consider discounted costs and returns over a long

[4] This is likely to be the case, given reasonable assumptions about the minimum acceptable marginal rate of return over period 1, the discount rate, and the rate of growth in yield potential. Both $1 + R_1 = 1/X_1$ and $1 + r = 1/W$ are likely to be larger than A, from which $Z = A^T X_1 W^{T-1} < 1$.

[5] Copies of the spreadsheet used in calculating the optimal replacement times reported below are available from the authors on request.

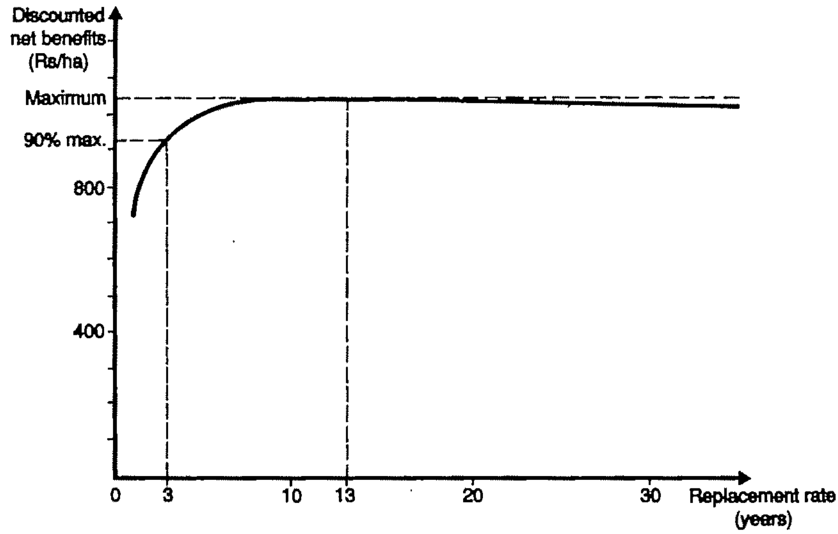


Figure 2. Discounted net benefits with different periods of varietal replacement

time horizon, a wide range of varietal replacement times will be consistent with near-optimal behavior.

Change in Parameters and Rate of Varietal Replacement

The impacts of changes in other parameters on T^* and T^{**} are summarized in table 1. Most of these effects (e.g., those for i, j, and p_s/p_g) accord with intuition, but several merit further explanation.

The higher the base yield, Y_0, the faster the rate of varietal replacement with either myopic or infinite time horizons. This result is driven by the model's assumptions that varietal improvement and farmer seed deterioration can be represented by an annual percentage increase or decrease. If the base yield is higher, a given percentage difference between an old and a new variety translates into a greater absolute yield gain, greater benefits, and a faster rate of varietal replacement.

Given the myopic, or single-period time horizon, increases in R_1 slow the rate of varietal turnover T^*. In the infinite time horizon case, a larger R_1 will lead to a greater T^{**}, as expected, but the larger the discount rate r, the lower will be T^{**}. The reason for the opposite effects of changes in R_1 and r given an infinite time horizon is that the difference $R_1 - r$ is related to the farmer's initial uncertainty about the yield of new varieties. If $R_1 - r$ is large, the desired seed replacement period is long. Keeping R_1 constant and raising r (or keeping r constant and lowering R_1) speeds varietal replacement by making farmers' perceptions of yield gains more nearly similar to actual yield gains. Furthermore, in the infinite time horizon case, a higher base discount rate, r, speeds varietal replacement by contributing to heavier discounting of future net benefits, so that waiting to change variety is less advantageous.

Uses of Seed Replacement Models

The model presented above can be used in several ways. First, if values can be assigned to all the other parameters, the predicted rates of varietal replacement can be found. Alternatively, values can be specified for several parameters and the required values of the other parameters

Table 1. Effects of Model Parameters on Rates of Varietal Replacement

Infinite Horizon Case (Optimal Replacement) T^{**}		Myopic Case (Minimum Profitable Replacement) T^*
$\partial T^{**}/\partial i < 0$		$\partial T^*/\partial i < 0$
$\partial T^{**}/\partial j < 0$		$\partial T^*/\partial j < 0$
$\partial T^{**}/\partial(p_s/p_g) > 0$		$\partial T^*/\partial(p_s/p_g) > 0$
$\partial T^{**}/\partial Y_0 < 0$		$\partial T^*/\partial Y_0 < 0$
$\partial T^{**}/\partial R_1 > 0$	$R_1 > r$	$\partial T^*/\partial R_1 > 0$
$\partial T^{**}/\partial r < 0$		

that will lead to a fixed level of T^* or T^{**} can be determined. We now postulate certain parameter values and apply the model to some hypothetical examples drawn from wheat research in post-green revolution Pakistan.

Demand for Wheat Seed in Pakistan

In the following analysis, i, the rate of genetic improvement for wheat varieties in Pakistan, is set at 0.75%, a relatively conservative figure slightly below Byerlee's estimate of 1.00% per annum for Pakistan's Punjab in the period since the introduction of semi-dwarf varieties. Byerlee also estimated that losses attributable to declining rust resistance in wheat in Pakistan were approximately 0.25% per year, but estimates for j comparable to the estimate for i are not available because j includes losses to seed intermixture or loss of germination potential as well as the losses to disease. Available estimates from other countries of annual yield losses for wheat grown from farmers' seed range from nil in one dryland area of Australia (Plater, personal communication) to 1.6% in Nepal (S. Biggs, personal communication). Selvaraj and Subramanian also found a 1.6% annual decline in the yield potential of rice, another self-pollinated crop, in India. The differences in results between these studies probably reflect differences in farmers' seed management practices as well as differences in disease and pest pressure. For the analysis of replacement wheat seed in Pakistan below, j is set initially at 0.75%.

The average wheat seed-to-grain price ratio in Pakistan is approximately 1.5 (Chaudhry and Heisey). A base yield Y_0 of 2,000 kilograms per hectare represents current yields for irrigated wheat in Pakistan, and the seed rate for wheat is assumed to be 100 kilograms per hectare, in line with farmers' current practice (Byerlee et al.).

The discount rates r, and R_1, which reflects farmers' initial uncertainty about the expected yield associated with replacement seed, are difficult to value appropriately. Interest rates varying from 12% to 150% per year have been reported in different studies of rural areas of developing countries (Ghatak, Sarap, Ahmed), with rates depending on the status of the borrower, the purpose of the loan, and the nature of the lending agency. For this analysis, r is initially set at 30% per annum to indicate a subjective, but unproven, belief in a certain degree of imperfection in rural capital markets. Following CIMMYT, we use 50% as the minimum acceptable rate of return over the initial crop cycle, R_1. CIMMYT proposed this figure for technologies that represent only simple adjustments to farmers' practice, such as seed of a new wheat variety for a farmer who has already adopted semi-dwarf wheat technology.

Substituting these parameters into expression (6) produces a value of three years for T^*, the myopic solution; using expressions (10) through (13) generates a value of thirteen years for T^{**}, the optimal replacement rate associated with an infinite time horizon. Ninety percent of the maximum discounted net benefits in the infinite time horizon case could be obtained if variety were replaced every three years.

If farmers face identical parameters and differ only with respect to year of initial varietal change (i.e., the calendar year in which $nT + t = 0$), the average length of time farmers have been using a given variety can be approximated by $(T + 1)/2$, where T is actual replacement time. In a sample from two major irrigated wheat-growing areas of the Punjab in 1985–86, farmers had been growing wheat varieties for an average of two and one-half to three years, which implies a replacement time of four to five years. The same study found farmers in an irrigated area of northwest Pakistan growing varieties for an average of over five years, suggesting a replacement time of over nine years (Heisey). These values lie between the times predicted by the myopic and infinite time horizon assumptions. This study, however, was made four years after the actual release of several good new varieties and may underestimate long-run varietal replacement times.

Aggregate average age of wheat varieties, weighted by the proportion of area sown to each variety, can be used as another estimate of T, or replacement time. This measure, however, depends in rather complicated ways not only on demand for replacement seed but also on the lag between varietal release and widespread seed availability, on the length of time it takes for farmers to become aware of potential replacement varieties, and on the degree to which farmers replace seed with seed from seed dealers or from other farmers; therefore, the average age measure may tend to overestimate T.

In any case, the mean weighted age of wheat varieties averaged 11.1 years for Pakistan's Punjab between 1978 and 1986 (Brennan and Byerlee), which is closer to the T^{**} predicted using the assumption of an infinite time horizon. It is still likely that farmers' wheat seed

replacement times lie somewhere between the extremes predicted by the two assumptions regarding time horizon.

Sensitivity of Results to Changing Parameters

The effects of varying assumptions about the wheat parameters on T^{**}, on the value of T for which 90% of the optimal benefits are obtained in the infinite horizon case, and on T^* are shown in table 2. All parameters are varied to a level one-third below and one-third above their base level. In addition i and j are reduced by 100%, to 0.

The seed-to-grain price ratio, seed rate, and base yield have almost no impact on the optimal rate of seed change T^{**}. Increasing the rate of varietal improvement or increasing the rate of seed deterioration both speed varietal replacement noticeably, although these effects become less pronounced as i and j move farther from zero. (Effects of increasing i or j also become less pronounced at higher levels of the other parameter). Both r and R_1 have a major effect on T^{**}, in opposite directions. Many different combinations of r and R_1 can be inserted into the model given the assumption of an infinite horizon. If this is done, equal differences $R_1 - r$ lead to approximately equal values of T^{**}, although given a fixed $R_1 - r$, T^{**} is lower for higher values of r. This implies that if an infinite horizon is assumed, farmers' uncertainty concerning yield of potential replacement varieties plays a much greater role than does the opportunity cost of working capital in determining optimal replacement time. Higher opportunity cost of capital in and of itself, with no changes in the uncertainty measure $R_1 - r$, does speed varietal replacement to a minimal extent.

Only the parameters R_1 and r have any noticeable effect on the initial slope of the net benefit curve for alternate replacement periods T in the infinite horizon model. This is indicated in table 2 in the column showing the replacement times at which 90% of the net benefits are obtained. In other words, only the uncertainty measure $R_1 - r$ substantially changes the range

Table 2. Sensitivity of Wheat Results to Different Parameter Values

Parameter	Value	T^{**} (Years)	90% of Optimum (Infinite Horizon Model) (Years)	T^* (Years)
p_s/p_g	1.00	13	3	1
	1.50	13	3	3
	2.00	14	3	5
Y_0	1333	13	3	4
	2000	13	3	3
	2667	13	3	2
i (%)	0.00	23	3	6
	0.50	15	3	4
	0.75	13	3	3
	1.00	12	3	3
j (%)	0.00	23	3	5
	0.50	15	3	3
	0.75	13	3	3
	1.00	12	3	3
S	67	13	3	2
	100	13	3	3
	133	13	3	4
r (%)	20	20	5	
	30	13	3	
	40	8	2	
R_1 (%)	33	5	1	3
	50	13	3	3
	67	20	4	3

Note: In each case, values of the other parameters are held at the initial levels specified in the text.

of replacement times for which net benefits are near optimal.

In the single period case, in contrast to the infinite horizon case, the uncertainty parameter R_1 has no perceptible effect on T^*. Only by moving R_1 considerably higher than reported in table 2 will T^* increase noticeably. The effects of i and j in the myopic case are similar to those in the infinite horizon case. Again in contrast to the infinite horizon case, T^* is noticeably affected by changes in p_s/p_g, Y_0, and S.

Conclusions

This paper has presented a framework for comparing the costs and benefits of seed replacement, which is then related to varietal replacement by assuming that the yield differences leading to varietal change result from yield improvements in available varieties and deterioration in the potential performance of seed retained by farmers. Parameters indicating the rates of yield improvement and farmers' seed deterioration are unlikely to be constant over time but may be affected by both partially predictable factors (e.g., investment in breeding research) and random events (e.g., changes in environmental conditions leading to changes in disease spectrums). In reality, even predictable factors such as investment in research will lead to small jumps in yield potential after varying periods of time rather than smooth year-to-year increases. Because breeders and seed supply agencies presumably use expected values in their planning, the assumptions that rates of increase in yield potential and decline in farmers' seed are constant are sufficient to draw conclusions on the likely impact on farmers' demand for seed. Changes in these parameters lead to the expected results: increasing the rate of yield improvement speeds varietal replacement; decreasing the rate of farmer seed deterioration slows varietal replacement.

The effects of other factors influencing seed change are strongly conditioned by the assumptions made about time horizon. Assumptions made about uncertainty associated with new seed have a marked influence on the rate of varietal replacement if farmers' time horizons are taken to be infinite. Assumptions made about seed price, in particular, affect the rate of varietal replacement in a single period horizon version of the model.

If there is reason to believe that the private and social costs and benefits of the rate of seed change diverge, the specification of demand for replacement seed has policy implications. For example, in the case of a varietal breakdown in disease resistance, there are many instances in which society would place greater value on avoiding a major disease epidemic than an individual farmer would, especially given the probability that such an epidemic would affect an individual farmer. Thus, it can be in society's interest to promote more rapid varietal replacement.

The analysis above indicates that, except for investment in research to promote faster yield improvement, the policy instruments available to influence seed demand will depend on farmers' time horizons. Desired varietal replacement times are already relatively small in short time horizon situations in which seed prices are likely to affect demand, and experience shows that farmers are willing to pay prices that guarantee returns to seed distributors and growers if they are convinced of the benefits of the new seed (Kelly, Asian Productivity Organization). This suggests that increasing the flow of information concerning the yield potential of new varieties is likely to be preferred to seed subsidies as a policy instrument.

Further research might explore several avenues. The model might be applied to data for different crops and different countries, certain parameters could be made endogenous, or related inputs and non-yield varietal characteristics could be considered. The behavioral specification could be improved to include risk preference through different assumptions on $v(\pi)$. Theoretical models that combine both time and risk preference over more than two periods, however, tend to be either conceptually intractable or theoretically unappealing (Anderson, Dillon, and Hardaker), even though decision making over time and under uncertainty have many common elements (Prelec and Loewenstein).[6] In addition, in any period, the farmers' choice might be framed as one among three alternatives: planting seed from the grain harvest, planting new seed of the same variety, and planting new seed of a new variety, which involves the greatest uncertainty. Such a specification would necessitate a rigorous specification of the time horizon relevant to varietal replacement and recognition that a plan viewed as optimal at one time might not appear optimal at another (Strotz). Different assumptions con-

[6] The effects of risk aversion on the rate of seed change are likely to be ambiguous (Lindner and Fischer).

cerning time horizon might not change comparative statics, but they do alter predictions considerably, a finding that likely applies to many models of decision making over time.

[Received November 1989; final revision received January 1991.]

References

Ahmed, Z. U. "Effective Costs of Rural Loans in Bangladesh." *World Develop.* 17(1989):357–63.

Anderson, J. R. "One More or Less Cheer for Optimality." *J. Aust. Inst. Agr. Sci.* 41(1974):195–97.

Anderson J. R., J. L. Dillon, and J. B. Hardaker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977.

Asian Productivity Organization. *Cereal Seed Industry in Asia and the Pacific.* Tokyo: Asian Productivity Organization, 1987.

Benzion, U., A. Rapoport, and J. Yagil. "Discount Rates Inferred from Decisions: An Experimental Study." *Manage. Sci.* 35(1989):270–84.

Brennan, J. P., and D. Byerlee. "The Rate of Crop Varietal Replacement on Farms: Measures and Empirical Results for Wheat." *Plant Varieties and Seeds,* forthcoming.

Byerlee, D. "Technical Change and Returns to Wheat Breeding Research in Pakistan's Punjab in the Post-Green Revolution Period." Mimeographed. Mexico D.F.: CIMMYT, 1989.

Byerlee, D., P. R. Hobbs, B. R. Khan, A. Majid, M. R. Akhtar, and N. I. Hashmi. *Increasing Wheat Productivity in the Context of Pakistan's Irrigated Cropping Systems: A View From the Farmer's Field.* Islamabad: PARC/CIMMYT Pap. No. 86–7, 1986.

Chaudhry, M. A., and P. W. Heisey. *Production and Marketing of Wheat Seed in Punjab.* Islamabad: Economic Analysis Network Spec. Rep. Ser. No. 7, 1988.

CIMMYT. *From Agronomic Data to Farmer Recommendations: An Economics Training Manual,* rev. ed. Mexico, D.F., 1988.

Feder, G. "Adoption of Interrelated Agricultural Innovations: Complementarity and the Impacts of Risk, Scale, and Credit." *Amer. J. Agr. Econ.* 64(1982):94–101.

——. "Farm Size, Risk Aversion and the Adoption of New Technology Under Uncertainty." *Oxford Econ. Pap.* 32(1980):263–83.

Feder, G., and G. T. O'Mara. "On Information and Innovation Diffusion: A Bayesian Approach." *Amer. J. Agr. Econ.* 64(1982):145–47.

Gafsi, S., and T. Roe. "Adoption of Unlike High-Yielding Wheat Varieties in Tunisia." *Econ. Develop. and Cultur. Change* 28(1979):119–33.

Ghatak, S. "On Interregional Variations in Rural Interest Rates in India." *J. Develop. Areas* 18(1983):21–34.

Heisey, P. W., ed. *Accelerating the Transfer of Wheat Breeding Gains to Farmers: A Study of the Dynamics of Varietal Replacement in Pakistan.* Mexico, D.F.: CIMMYT, 1990.

Herath, H. M. G., J. B. Hardaker, and J. R. Anderson. "Choice of Varieties by Sri Lanka Rice Farmers: Comparing Alternative Decision Models." *Amer. J. Agr. Econ.* 64(1982):87–93.

Kelly, A. F. *Seed Planning and Policy for Agricultural Production.* London: Belhaven Press, 1989.

Kislev, Y., and N. Shchori-Bachrach. "The Process of an Innovation Cycle." *Amer. J. Agr. Econ.* 55(1973):28–37.

Lindner, R. K., and A. J. Fischer. "Risk Aversion, Information Quality and the Innovation Adoption Time Lag." Mimeographed. Adelaide, Australia: University of Adelaide, 1981.

Lindner, R. K., A. J. Fischer, and P. Pardey. "The Time to Adoption." *Econ. Letters* 2(1979):187–90.

Loewenstein, G., and D. Prelec. "Anomalies in Intertemporal Choice: Evidence and an Interpretation." Center for Decision Research Work. Pap., University of Chicago, 1989.

Loewenstein, G., and R. H. Thaler. "Anomalies: Intertemporal Choice." *J. Econ. Perspectives* 3(1989):181–93.

McMullen, N. *Seeds and World Agricultural Progress.* Washington DC: National Planning Association Rep. No. 227, 1987.

Nowshirvani, V. F. "Land Allocation Under Uncertainty in Subsistence Agriculture." *Oxford Econ. Pap.* 23(1971):445–55.

Prelec, D., and G. Loewenstein. "Decision Making Over Time and Under Uncertainty: A Common Approach." Center for Decision Research Work. Pap., University of Chicago, 1990.

Sarap, K. "Transactions in Rural Credit Markets in Western Orissa, India." *J. Peasant Stud.* 15(1987):83–107.

Selvaraj, J. A., and P. Subramanian. "Influence of Genetic Contamination on Seed Yield and Quality of IR50." *Int. Rice Res. Newsletter* 13(1988):26.

Strotz, R. H. "Myopia and Inconsistency in Dynamic Utility Maximization." *Rev. Econ. Stud.* 23(1955–56):165–80.

Cost Effectiveness and Equity Aspects of Soil Conservation Programs in a Highly Erodible Region

Douglas L. Young, David J. Walker, and Paul L. Kanjo

The Conservation Reserve (CRP) and Conservation Compliance Programs could divide the soil conservation burden between farmers and taxpayers. In a highly erodible southeastern Washington region, however, a uniform region-wide CRP bid cap and relaxed compliance requirements resulted in little or no projected burden for farmers in arid, less productive subregions. In contrast, farmers in a more productive subregion were projected to bear 50% or more of the costs of soil conservation. The projected government cost per ton of soil conserved also increased threefold from the most to the least productive subregion.

Key words: Conservation Compliance, Conservation Reserve Program, cost distribution, cost effectiveness, soil conservation.

The 1985 Food Security Act (FSA) signaled a watershed in U.S. soil conservation policy. The act expanded taxpayer-financed soil conservation incentives by establishing the Conservation Reserve Program (CRP) and by extending cost sharing for approved conservation practices. Furthermore, the act broke with precedent by enacting the Sodbuster, Swampbuster, and Conservation Compliance provisions, which deny U.S. Department of Agriculture (USDA) program benefits to noncomplying farmers, thereby potentially transferring some of the conservation burden to farmers. Sodbuster and Swampbuster withhold USDA commodity and other program benefits from growers who convert to cropland highly erodible land or wetland. Conservation compliance requires those farming highly erodible land to file by 1990 and implement by 1995 an acceptable conservation farm plan to remain eligible for USDA program benefits.

Both equity and cost effectiveness issues are important in evaluating the 1985 FSA. Two equity issues are (*a*) the distribution of program costs between farmers and taxpayers and (*b*) the distribution of costs among farmers with differing land endowments. Evaluating the first issue involves estimating net taxpayer expenditures and changes in farmers' net incomes. Evaluating the second requires computing the costs of conservation compliance, net of any gains from CRP participation, for farmers whose land differs in erodibility and productivity. Evaluating program cost effectiveness requires identifying total cost per unit of environmental damage averted.

Dicks, Putman and Alt, and English and Frohberg have estimated the aggregate private cost to farmers of meeting conservation compliance. Barbarika and Dicks have computed the national total of a selected mix of public and private costs of achieving conservation compliance. Ervin, Heffernan, and Green have speculated theoretically on the equity impacts for farmers and taxpayers of the FSA conservation provisions. To the best of our knowledge, no studies have empirically measured the full distributional impacts of the FSA conservation provisions in selected regions of the United States.

The objectives of this paper are to measure the joint influence of the conservation compliance and CRP provisions in the highly erodible Palouse region of southeastern Washington on (*a*) the distribution of costs between taxpayers and farmers, (*b*) the distribution of costs among farmers with differing land endowments, and (*c*) the public and private cost effectiveness of soil

Douglas L. Young and Paul L. Kanjo are, respectively, a professor and a former research assistant in the Department of Agricultural Economics, Washington State University. David J. Walker is a professor of agricultural economics, University of Idaho.

conservation. Although the CRP bid cap is uniform throughout the study region, three subregions with different soil erodibility and productivity are present. A regional rather than a national focus is appropriate to show how a uniform bid cap can impose widely varying costs of conservation compliance within a single region.

The distribution between public and private costs is evaluated for alternative conservation compliance standards (soil erosion limits) and various uniform regional CRP bid caps. Results are compared over the three subregions. Prior to presenting results and conclusions, we review the concept of cost effectiveness and its application to soil conservation, describe the mixed integer programming model used, and review the data for the study region.

Cost Effectiveness: Concepts and Applications

Cost effectiveness ratios are frequently used to compare alternative practices and policies for abating environmental damage. Ideally, cost effectiveness in conserving soil should be expressed as cost per unit of total offsite and onsite economic damage avoided (U.S.GAO 1983). However, the difficulty in quantifying damage has led nearly all researchers and regulatory agencies to substitute the quantity of soil eroded, as measured by the Universal Soil Loss Equation (USLE), for economic damage (Monteith et al.). That method is accurate only when the incremental damage is constant for each ton of soil eroded, which is only approximately true. Generally, on-site productivity losses from erosion are greater the shallower is the soil. Offsite losses resulting from sediment flows into surface waterways with high value uses are higher than those from flows into deposition plains. Faced with the usual data limitations, however, cost per ton of soil conserved was used in this study.

The utilized cost-effectiveness ratio emphasizes the soil conservation objectives of conservation compliance and CRP and, to the extent sedimentation is correlated with erosion, water quality objectives. Nonenvironmental objectives of CRP are not emphasized by the selected cost-effectiveness ratio but are considered elsewhere in the analysis. Specifically, government supply control costs and farm income changes are accounted for separately.

The literature contains many evaluations of soil and water conservation practices and policies, but few studies measure and compare public versus private costs. Most report only private cost effectiveness, measured in terms of farm income lost per ton of soil conserved (e.g., Mitchell, Brach, and Swanson; Miller and Gill, Spurlock and Clifton; Kramer et al.; Seale, Hubbard, and Kaiser). Dicks and Young, and Park and Monteith, report public (taxpayer) cost effectiveness.

A few water quality studies have attempted to compare public and private cost components. A U.S. Water Resource Council study partitioned cost burdens for water projects and Lake, Hanneman, and Oster partitioned cost burdens for water quality under PL 92-500 on a national level.

Model

This study assesses the net economic impacts on farmers and taxpayers of alternative mixes of Conservation Compliance levels and CRP bid caps for a southeastern Washington study region. A farm-level mixed integer programming model was used to project profit-maximizing farmer responses to the provisions of the FSA of 1985 including its extensive cross-compliance features. The mixed integer model in general form is

$$(1) \qquad \mathrm{Max}_{x,z}\ \pi = c\,x + d\,z$$

$$A\begin{bmatrix} x \\ \text{---} \\ z \end{bmatrix} \leq b$$

$$x \geq 0$$

$$z \in \{0,1\},$$

where π is annual farm profit, x is a vector of linear programming activities, z is a vector of zero-one variables, c and d are vectors of objective function coefficients, A is a matrix of technical coefficients, and b is a vector of constraint levels. Except for the presence of the zero-one (integer) variables, (1) is a standard linear programming model.

Integer zero-one variables provided a tractable procedure for modeling the interrelated constraints within the FSA. Commodity program and CRP participation were modeled with five mutually exclusive zero-one participation variables:

(2) *SWBMNOCRP*, *SWBMCRP*, *SWMBP*, *SWPBM*, and *SWBP*,

where $SW(B)M(P)$ means sell wheat (barley) in the market (government program) and (NO) CRP means (no) participation in the Conservation Reserve Program. Because participation in at least one commodity program and/or in CRP makes growers who farm erodible land subject to conservation compliance, it is not necessary to distinguish CRP status for the last three variables in (2). A constraint forcing the five variables to sum to one ensures that they are mutually exclusive.

The presence of the optimal participation status variable in the basis enforces or relaxes program constraints as appropriate. Constraint (3) illustrates this procedure for conservation compliance. Conservation compliance erosion constraints for erodible land classes are

$$(3) \qquad -d(SWBMNOCRP) + \sum_{i=1}^{n} a_{ij}X_i \leq b_j, \qquad j = 1, \ldots, J,$$

where d is an arbitrarily large positive number, a_{ij} is the erosion rate (tons/acre/year) of production activity X_i on the jth land class, and b_j is the erosion limit (tons/year) for jth land class. To simplify the analysis of the impact of differing general levels of conservation compliance on the representative farms in this study, expression (3) abstracts from the actual field-by-field basis for determining compliance constraints. A single farm-wide erosion rate limit was employed for each compliance level examined.

Constraint (4) precludes CRP participation if $SWBMNOCRP$ is in the basis.

$$(4) \qquad t(SWBMNOCRP) + \sum_{j=1}^{J} r_j \leq t,$$

where t is total farm acreage qualifying for CRP and r_j is acres of CRP from the jth land class.

Constraint (3) enforces the conservation compliance provision of the FSA. This provision requires all growers with erodible land to implement a farm plan which meets soil loss limits to be eligible for government programs. The barley program, the wheat program, and CRP are the most important government programs in the study region and are included in the analysis. Only nonparticipation in all these programs, as indicated by $SWBMNOCRP$'s presence in the basis, removes the soil erosion constraints. The participation status variables were also used to link receipt of deficiency payments to program participation.

Similar procedures were used to enforce intercommodity cross compliance. Thus, farmers cannot exceed base acreage in other program crops if they participate in the government program for at least one crop. Another set of zero-one variables was used to force selection of a single rotation-tillage combination over the farm consistent with farmers' actual cultivation practices for the steep Palouse hills, which include intermingled, irregularly shaped land classes. The model also incorporated separate \$50,000 payment limitations for deficiency payments and for CRP.

Data and Procedures

The model was applied to three representative farms which reflected land characteristics, farm size, and crop yields of the western, central, and eastern subregions of the 1.2 million-acre Palouse region in Whitman County, Washington. Annual precipitation varies across subregions: 12 to 15 inches in the western, 15 to 18 inches in the central, and 18 to 22 inches in the eastern subregion. The 1,000-acre eastern and central subregion representative farms and the 2,000-acre western farm were divided into land groups by erodibility and productivity proportional to the composition of cropland in the subregions (USDA). Region-wide, over 80% of the cropland is classified as highly erodible, and most of this is also highly productive. In the eastern subregion, 77.7% of all cropland is highly erodible and highly productive, while 67.7 and 63.2% of the central and western subregions are in this category (see table 1). About 50% of the Palouse lies in the higher precipitation eastern subregion.

The Pacific Northwest adaptation of the USLE was used to obtain annual average erosion estimates by tillage-rotation system in each subregion (McCool and George). Natural erodibility varies considerably by land class within a subregion and across subregions (see table 1). Table 1 also portrays erosion tolerance values (T) and erodibility index (EI) values. Combining USLE "C factors" for management systems with land-climate-based "natural erodibility factors" yielded erosion rates ranging from 43 tons per acre per year for summer fallow on highly erodible low-productivity land in the western subregion to less than 1 ton per acre on long-term CRP or grass set aside on all land classes and subregions.

Crop yield projections are based upon yield estimates by soil mapping unit as listed in the

Table 1. Natural Erodibility, *T*-Values, and EI Values By Land Class and Subregion

Palouse Subregion	Land Class	Percent Farm	Natural Erodibility (R.K.LS)	Weighted Average *T*	Weighted Average EI
East	NE	12.4	11.00		
	HH	77.7	57.21	4.9	11.7
	HM	7.8	65.08	5.0	13.0
	HL	2.1	59.11	3.7	16.0
Central	NE	16.5	12.20		
	HH	66.7	50.50	4.9	10.3
	HM	9.4	70.25	4.1	17.1
	HL	7.4	69.59	4.7	14.8
West	NE	17.4	15.97		
	HH	63.2	46.36	4.8	9.7
	HM	12.6	44.09	3.7	11.9
	HL	6.8	60.96	3.8	16.0

Whitman County Soil Survey (USDA). These estimates were updated to 1992 using statistical yield trend equations and weighted by acreage to obtain land class estimates. Yields varied greatly over the three precipitation subregions (see table 2). Average wheat yields on the dominant highly erodible, high productivity land class ranged from 57 to 82 bushels per acre from the western to the eastern subregions. Based on Extension Service judgments and experimental plot data (Taylor), a yield penalty of 4% was imposed when moving from conventional to minimum tillage and 16% when moving from conventional to no-tillage in the central subregion only.

Production costs net of land, labor, and management were based on budgets by Caplan et al. (1987a, b, c). Conventional and minimum tillage costs were similar, but no-till costs were 1% to 3% higher for the included rotations. Permitted land uses included: (*a*) alternative crop rotations, (*b*) three tillage levels (no, minimum, and conventional), (*c*) grass or fallow for set-aside, and (*d*) Conservation Reserve Program. Alternative rotations in the eastern subregion included winter wheat/spring barley/dry peas, and winter wheat/dry peas. Winter wheat/spring barley/summer fallow and continuous spring barley comprised the central region rotation choices and winter wheat/summer fallow and flexible (depending upon spring soil moisture) spring barley were available in the western subregion.

Expectations of future prices can influence farmers' choices of farm plans to meet the 1990 Conservation Compliance deadline. A ten-year (1988–97) period was chosen as the planning horizon for the analysis and for the price expectations. This period is consistent with the ten-year contract period for CRP enrollment and also encompasses the five-year (1990–94) conservation compliance implementation period. All estimates of average crop yields and prices are for 1992, the midpoint and assumed average of the ten-year planning horizon. All prices and costs are measured in 1987 dollars. Target prices for

Table 2. Projected 1992 Crop Yields by Subregion and Land Class

Palouse Subregion	Crop[a]	Land Class[b] NE	HH	HM	HL
East	WW	81.5	80.8	46.3	36.6
	SB	1.99	1.71	1.49	1.49
	DP	1714	1930	974	920
Central	WW	71.8	86.3	47.6	28.3
	SB	1.61	1.64	1.56	0.95
West	WW	49.0	57.3	37.3	16.6
	SB	1.08	1.11	1.03	0.61

[a] WW is winter wheat (bu/ac), SB is spring barley (t/ac), DP is dry peas (lb/ac).

[b] NE is nonerodible by USDA criterion, HH is highly erodible and high productivity, HM is highly erodible and medium productivity, HL is highly erodible and low productivity.

wheat and barley for 1992 were based on a continuation of the downward trend established in the 1985 FSA target price schedule. Market prices were based on local Cooperative Extension Service projections (Robert Sargent, Coop. Extens. Serv., Washington State University, personal communication 1988). These procedures led to respective market and target 1992 real price expectations of $3.00 and $4.00 per bushel for wheat, $80.00 and $98.46 per ton for barley, and $9.08 per hundredweight for dry peas which are not a program crop. The market price expectations were slightly higher than real farm-level prices in the Palouse during 1990, the first year of the conservation compliance implementation period, but they underestimated actual market prices in the late 1980s. Results for some limited price sensitivity analysis, using higher market grain prices, are also reported.

Mathematical programming models with constant price and farm program expectations of the type used here provide a tractable procedure for measuring the impact of the CRP and its complex interrelationship with other FSA provisions, but they suffer the obvious limitation of ignoring endogenous adjustments in commodity prices. Some general equilibrium modeling results, however, have indicated this may not be a major problem. Hertel and Preckel (p. 2) conclude: "The estimated effect of increased CRP enrollment on commodity prices is modest and largely depends on interactions with other farm programs. Previous research has probably overstated the commodity price effects of the CRP because of insufficient treatment of cross-commodity effects." For example, Hertel and Preckel projected prices for soybeans, corn, and wheat to rise by only 1.0% to 1.5% for a four-million-acre increase in CRP enrollment above the current ceiling.

Another argument favoring a fixed prices regional modeling approach is the existence of some regional autonomy in determining CRP bid rates, CRP bid pool regions, and alternative conservation systems for conservation compliance. Changes in CRP bid rates or compliance standards for the Palouse are not necessarily followed elsewhere in the country. Consequently, they may not generate significant shifts in national supply.

Program yields for wheat and barley were assumed equal to the farm-wide projected yields in each subregion as listed in table 2. Acreage Reduction Program (ARP) requirements were assumed to remain at the then current (1987–88) levels of 27.5% for wheat and 20% for barley. If average ARP rates over the ten-year planning horizon are below these levels, our estimates of government deficiency payments and farmers' net incomes will be biased downwards, *ceteris paribus*.

The magnitude and distribution of taxpayer and farmer costs of the conservation compliance and the conservation reserve programs for the study region were determined by initially solving the profit-maximizing integer programming model of each representative farm for a benchmark scenario which included commodity policies but no conservation policies. The model was then solved for profit-maximizing solutions under various levels of conservation compliance standards and CRP rents. Farmer costs of meeting conservation requirements were computed by subtracting the objective function value for a given policy from that for the benchmark. Government costs, comprised of commodity program deficiency payments and CRP rents, were computed by subtracting outlays for these programs in the benchmark run (which included only deficiency payments) from these outlays for each conservation policy run. This approach accounted for offsetting savings in government commodity programs when land was put in CRP. Administrative costs were not included among taxpayer outlays because of a lack of reliable data on their magnitude. Consequently, the study measures only direct government payments to farmers.

Per acre costs and cost effectiveness ratios are reported separately for farmers and taxpayers. Subtracting average farm-wide soil loss for a given conservation policy from soil loss in the benchmark run provides a measure of soil conserved. This result serves as the denominator in computing cost effectiveness ratios. Farmer and taxpayer ratios are not summed on a one-to-one basis to form an "overall cost-effectiveness ratio." This avoids imposing a particular social welfare function with respect to how costs borne by farmers and taxpayers should be weighted. Policy makers are free to assign any weighting they consider appropriate.

Results

In the profit-maximizing solution for the benchmark run, farms in all three subregions participated in wheat and barley programs and farmed all acres except those required to meet ARP requirements. Conventional tillage was used in the eastern and central region, but minimum tillage

was used in the western region where it was slightly less costly and carried no yield penalty. The benchmark solutions generated annual erosion of 10.9 tons per acre in the eastern region, 8.7 tons per acre in the central region, and 10.7 tons per acre in the western region. Annual net returns to land, labor, and management were $77.76 per acre in the eastern region, $62.56 per acre in the central region, and $26.85 in the western region.

Table 3 reports the impacts of four conservation compliance standards assuming the prevailing $60 per acre county-wide CRP rental payment. It also shows results for four CRP rates assuming the "typical" (1–2T) compliance standard. Early interpretations of conservation compliance indicated that farm plans must achieve soil loss tolerance (1T), but subsequent provision for alternative conservation systems has relaxed this standard. Consequently, results are presented for 1T–2T and 2T as well. The 1T–2T standard varies between 1T and 2T in direct proportion to the erosion index for the farm.

The results in table 3 show CRP was always profitable in the central and western subregions, even without the enforcement stick of conservation compliance. Indeed, under the crop prices used here, it was profitable under all scenarios on the 2,000-acre western subregion farm to enroll highly erodible land up to the $50,000 CRP payment limit.

When erodible acres are enrolled in CRP in response to conservation compliance and/or due to the inherent profitability of CRP, government deficiency payments fall because program crop bases are cut proportionately as land is enrolled in CRP. As shown in table 3, these deficiency payment savings vary by subregion and program scenario but are generally less than the CRP costs. Total government outlays net of commodity program savings are also reported in table 3. As expected, these outlays are highest in the low-yielding, low rainfall western subregion where $60 per acre CRP rents confer considerable subsidies beyond break-even levels.

The government costs in table 3 can be compared to cost estimates in the literature. Dicks and Young estimated the government cost, net of commodity program savings, of the 8.8 million acres enrolled in the February 1987 CRP bidding round. The estimated nationwide average cost was $35 per enrolled acre. The results in table 3 report costs per all cropland acres. Multiplying the "$60/ac CRP, 1–2T" scenario results in table 3 by the ratio of farm size to CRP land gives costs on a comparable per enrolled acre basis. This procedure yields government costs of $25.54, $24.62, and $33.81 per enrolled acre for the eastern, central, and western subregions of the Palouse, which are similar to Dicks and Young's $35 per acre nationwide average.

In the productive eastern subregion, a strict 1T conservation compliance standard cut erosion by over 60% or by 6.8 tons per acre. Over half of the annual cost was borne by farmers who incurred $1.90 per ton of soil conserved versus $1.44 per ton borne by taxpayers. As expected, relaxing compliance standards reduces soil conservation. Also, consistent with Barbarika and Dicks' national study, the average cost per ton of soil conserved increases as soil savings increase.

In the western and central subregions, the combination of conservation compliance and CRP generally increased farmers' net returns to land, labor, and management. This increase shows up as a negative farmers' cost per ton of soil conserved or a net subsidy. Only at the 1T compliance level in the central subregion do farmers in these two subregions bear any costs of soil conservation. This is a consequence of the inherent profitability of CRP on the low-yielding, erodible land classes in these two subregions.

The estimates in table 3 of Palouse farmers' costs in meeting conservation compliance can also be compared to available nationwide estimates. Dicks, and Putman and Alt independently estimated that controlling erosion to 1 T nationwide without CRP would cost farmers an average of $13 per erodible acre. Dicks' estimate for the Pacific Region was $17 per acre. The "no CRP, 1–2T" row in table 3 approximates the policy scenario for the national estimates. Adjusting the cost estimates in table 3 to a comparable per erodible acre basis, eastern, central, and western Palouse farmers incurred $23.45, $18.73, and $12.25, respectively, to meet compliance. While the Palouse values are on average similar to Dicks' Pacific Region estimate, the marked subregional variation within a single CRP bid pool illustrates the differences that are concealed by aggregate estimates.

Table 3 also provides similar results on the impact of varying CRP rates assuming a constant 1–2 T conservation compliance standard. For all subregions, at $40, $60, and $80 CRP rents, CRP provides a profitable means for a farmer to meet conservation compliance. Thus, taxpayers incur at least a portion of the cost of

Table 3. Impact of Conservation Compliance Standards and CRP Rates on Soil Conserved and Distribution of Costs

				Cost Changes ($/ac)				Cost of Soil Conserved ($/ton) Borne by	
				Taxpayers					
Palouse Subregion	Conservation Compliance Standard	Gross CRP Rate ($/ac)	Soil Conserved (t/ac)[a]	Deficiency Payments	CRP	Total	Farmers[b]	Farmers	Taxpayers
East	1T	60	6.8	−13.32	23.16	9.84	12.92	1.90	1.44
	1–2T	60	5.3	−6.02	10.49	4.47	7.95	1.50	0.84
	2T	60	3.6	0	0	0	3.24	0.90	0
	None	60	0	0	0	0	0	[c]	[c]
	1–2T	None	4.7	−4.86	0	−4.86	20.54	4.37	−1.01
	1–2T	40	5.3	−6.02	6.99	0.97	11.45	2.16	0.18
	1–2T	60	5.3	−6.02	10.49	4.47	7.95	1.50	0.84
	1–2T	80	5.3	−14.18	32.86	18.68	3.55	0.67	3.60
Central	1T	60	5.0	−16.60	25.25	8.65	1.25	0.25	1.72
	1–2T	60	4.0	−9.83	16.65	6.82	−2.32	−0.58	1.70
	2T	60	1.6	−4.08	11.33	7.25	−7.57	−4.73	4.39
	None	60	1.5	−3.05	10.08	7.03	−8.68	−5.79	4.84
	1–2T	None	3.3	−7.88	0	−7.88	15.64	4.74	−2.38
	1–2T	40	4.0	−9.83	11.10	1.27	3.24	0.81	0.32
	1–2T	60	4.0	−9.83	16.65	6.82	−2.32	−0.58	1.70
	1–2T	80	3.9	−15.65	33.92	18.27	−9.44	−2.42	4.68
West	1T	60	3.7	−8.99	25.00	16.11	−3.37	−0.91	1.84
	1–2T	60	5.0	−10.92	25.00	14.08	−9.05	−1.81	2.79
	2T	60	4.5	−8.89	25.00	16.11	−14.22	−3.16	3.56
	None	60	4.5	−8.89	25.00	16.11	−14.22	−3.16	3.56
	1–2T	None	7.5	0	0	0	10.12	1.35	0
	1–2T	40	5.7	−11.78	20.62	8.84	−5.19	−0.91	1.55
	1–2T	60	5.0	−10.92	25.00	14.08	−9.05	−1.81	2.79
	1–2T	80	8.4	−5.85	25.00	19.15	−11.76	−1.40	2.28

[a] Soil conserved equals the difference between erosion at no-conservation-policy benchmark and with the policy.
[b] Farmers' increased (decreased) cost equals reduction (expansion) in net income compared to benchmark.
[c] Undefined because changes in taxpayer and producer cost and soil conserved with the policy equal zero.

soil conservation. In the western subregion, farmers continue to earn pure subsidies even at the $40 CRP rental rate.

In the eastern and central subregions under the no-CRP scenario, table 3 displays the interesting result of a net saving by taxpayers. This result flows from the profit-maximizing choice to meet the conservation compliance standard by privately grassing out some of the least productive erodible land on the farm. With fewer acres planted, government deficiency payments fall. Planting grass was more profitable than exiting the wheat program to avoid the conservation requirement. Given the $1.00 per bushel gap between market and target wheat prices, there is a strong incentive for program participation.

The uniform county-wide CRP bid cap produces large differences in farmer cost among subregions. In eastern Whitman County, farmers bear 64% of conservation costs. In central and western Whitman county, farmers enjoy net benefits (rather than costs) from the conservation programs. In the eastern subregion, little land can be profitably enrolled in the CRP. In the other two regions, it is profitable to enroll erodible land in the CRP at the $60 per acre bid cap.

The relatively high windfall gains from CRP payments to farmers in less productive subregions underscore the potential improvement in program cost effectiveness which could be achieved by differentiating CRP bid caps by land productivity, even within counties. However, program administrators were unwilling to undertake this degree of geographic differentiation, perhaps because of concerns about administrative feasibility.

These results, which project "excess" CRP rental payments to the less productive subregions in this southeastern Washington county, are mirrored at the national level (U.S. GAO 1989). The General Accounting Office study showed that bid caps in counties with relatively unproductive qualifying land, primarily in the great plains and mountain states, were sometimes 200% to 300% of local cash rental rates for comparable land. Furthermore, USDA failed to adequately implement congressional guidelines in 1988 to limit CRP rates to local cash rental rates (U.S. GAO 1989).

Overall, soil conservation gains in table 3 show less response to changes in CRP bid rates than they do to changes in conservation compliance standards. Some results in table 3 might at first seem anomalous, but this is due to the discrete nature of the activity set. An example is the relatively high soil savings (7.5 tons/acre) in the western subregion when no CRP rental payment is paid. This soil saving is due to the adoption of no-till on all cropland to meet the compliance standard. This practice conserves more soil farm wide than enrolling the most erodible land in CRP and cultivating the remainder conventionally.

Again, actual farmer response to the FSA compliance provision will depend upon prices and farm programs in the future. While 1990 wheat and barley prices were roughly similar to those used in this analysis, ARP rates had declined, and the 1990 farm bill brings further changes.

Some limited sensitivity analysis to barley and wheat prices showed no impact on land use and program participation in the central and western subregions but some impact in the high productivity eastern subregion. Increasing wheat market prices from $3 to $4 per bushel and barley from $80 to $98 per ton while assuming the standard $60 per acre CRP rent and 1T–2T compliance standard made it profitable for the more productive eastern subregion farm to exit conservation compliance, CRP, and commodity programs. Without the discipline of conservation compliance, projected erosion increased from 5.6 to 12.5 tons per acre. In contrast, even at the higher grain prices, the $60 per acre CRP rate made it profitable for lower yielding central and western subregion farms to comply with the 1T–2T compliance requirement to remain eligible for CRP. The central and western subregion farms continued to profitably meet the 1T–2T compliance requirement with exactly the same CRP enrollments, cropping rotations, and tillage systems as were used under the base prices.

Conclusions and Policy Implications

Two central conservation provisions of the 1985 farm act, the Conservation Reserve Program and Conservation Compliance, have the potential to promote a sharing of the soil conservation burden between farmers and taxpayers. The analysis for the study region, however, shows that whether this sharing actually occurs and the degree to which it occurs depend upon the land resource base and the structure of CRP rental rates and compliance standards.

One feature of policy design contributed strongly to both the inequity and the low cost effectiveness of erosion control under the 1985 Food Security Act in this regional case study.

That feature is the uniform CRP bid cap over (multi) county regions, which, like the Palouse, contain cropland of widely varying productivity and erodibility. This feature helps explain why projected net costs to farmers over three subregions under current CRP rents and compliance standards ranged from an $8 per acre reduction in net income to a $9 per acre gain. Taxpayer cost effectiveness per ton of soil conserved dropped three-fold from the eastern subregion to the arid western subregion. These consequences of the uniform bid cap arise primarily from varying land productivity rather than from particular price assumptions.

An often recommended solution to the bid cap problem is to return to a true competitive bid system (U.S. GAO 1989, Taff and Runge). A competitive system was used in the first CRP bidding round and then abandoned. Once the bid caps were initiated, they became de facto government offer prices. If political inertia or perceived administrative problems prevent return to a genuine competitive bid system, a reasonable compromise would be to calibrate CRP bid caps more closely to land productivity and/or environmental vulnerability. Targeting the CRP more to environmentally vulnerable areas as in the 1990 farm bill will also improve the cost effectiveness of the program. Targeting reallocates CRP dollars from low yielding, moderate erosion areas to areas with more environmental benefits.

This study showed that tightening compliance standards was a much more effective means of decreasing soil loss under the assumptions employed than boosting region-wide CRP rents. This finding may justify the concern among some observers that too much relaxation of conservation compliance under the guise of alternative conservation systems could cause large soil conservation losses.

[Received November 1989; final revision received November 1990.]

References

Barbarika, Alexander, Jr., and Michael R. Dicks. "Estimating the Costs of Conservation Compliance." *J. Agr. Econ. Res.* 40(1988):12–20.

Caplan, Arthur, H. Hinman, T. Hoffman, and D. McCool. *Crop Enterprise Budgets, Selected Tillage Systems, Central Whitman County, Washington.* Coop. Extens. Serv. EB 1433, Washington State University, 1987a.

——. *Crop Enterprise Budgets, Eastern Whitman County, Washington.* Coop. Extens. Serv. EB 1437, Washington State University, 1987b.

——. *Crop Enterprise Budgets, Selected Tillage Systems, Western Whitman County, Washington.* Coop. Extens. Serv. EB 1427, Washington State University, 1987c.

Dicks, Michael R. "What Will It Cost Farmers to Comply with Conservation Compliance?" *Agr. Outlook,* No. 561, 1986.

Dicks, Michael R., and C. Edwin Young. "Targeting the Conservation Reserve Program for Economic Efficiency." Paper presented at the SAEA meetings, New Orleans LA, 1–3 Feb. 1988.

English, Burt C., and Klaus K. Frohberg. "Executive Report on the T-Study." CARD Rep., Iowa State University, 1987.

Ervin, David E., William D. Heffernan, and Gary P. Green. "Cross-Compliance for Erosion Control: Anticipating Efficiency and Equity Impacts." *Amer. J. Agr. Econ.* 66(1984):273–78.

Hertel, Thomas, and Paul V. Preckel. "Commodity-Specific Effects of the Conservation Program." *J. Agr. Econ. Res.* 40(1988):2–11.

Kramer, R. A., W. T. McSweeny, W. R. Kaiser, and R. W. Stavros. "An Evaluation of Alternative Policies for Controlling Agricultural Nonpoint Source Pollution." *Water Resour. Bull.* 20(1984):841–46.

Lake, E. E., W. M. Hanneman, and S. M. Oster. *Who Pays for Clean Water: The Distribution of Water Pollution Control Costs.* Boulder CO: Westview Press, 1979.

McCool, D. K., and G. O. George. "A Second Generation Adoption of the Universal Soil Loss Equation for Pacific Northwest Drylands." Paper No. 83-20661 presented at Amer. Soc. Agr. Eng. summer meeetings, Montana State University, 1983.

Miller, W. L., and J. H. Gill. "Equity Consideration in Controlling Nonpoint Pollution from Agricultural Sources." *Water Resour. Bull.* 12(1976):253–61.

Mitchell, Kent J., John C. Brach, and Earl R. Swanson. "Costs and Benefits of Terraces for Erosion Control." *J. Soil and Water Conserv.* 35(1980):233–36.

Monteith, T. J., R. A. Sullivan, T. M. Heidtke, and W. C. Sonzogni. *Watershed Handbook: A Management Technique for Choosing Among Point and Nonpoint Control Strategies.* Chicago: EPA Great Lakes National Program Office, 1981.

Park, William M., and Steven G. Monteith. "Cost Effectiveness of the Variable Cost-Share Option in the Agricultural Conservation Program." *J. Soil and Water Conserv.* 44(1989):173–76.

Putman, John, and Klaus Alt. "Erosion Control: How Does It Change Farm Income?" *J. Soil and Water Conserv.* 42(1987):265–67.

Seale, R. D., J. W. Hubbard, and E. H. Kaiser. "Subsidy and Tax Effects of Controlling Stream Sedimentation in South Carolina." *J. Soil and Water Conserv.* 40(1985):144–48.

Spurlock, Stan R., and Ivery D. Clifton. "Efficiency and Equity Aspects of Nonpoint Source Pollution Control." *S. J. Agr. Econ.* 14(1982):123–29.

Taff, Steven, and C. Ford Runge. "Wanted: A Leaner and Meaner CRP." *CHOICES,* no. 1 (1988), pp. 16–18.

Taylor, Barbara. Perceived Profitability in Farmer's Adoption of Soil Conservation Tillage. M.A. thesis, Washington State University, 1982.

The On-Farm Costs of Reducing Groundwater Pollution

Scott L. Johnson, Richard M. Adams, and Gregory M. Perry

Agricultural chemicals are a source of groundwater pollution in some areas. Regulatory options to reduce such nonpoint pollution imply costs to producers. By integrating plant simulation, hydrologic, and economic models of farm-level processes, this study evaluates on-farm costs of strategies to reduce nitrate groundwater pollution. The empirical focus is on intensively managed, irrigated farms in the Columbia Basin of Oregon. Results suggest that changes in timing and application rates of nitrogen and water reduce nitrate pollution with little loss in profits. Once such practices are adopted, further reductions in nitrates can be achieved only at increasing costs to producers.

Key words: bioeconomic modeling, groundwater pollution, nitrates, on-farm costs.

The adoption of pesticides and inorganic fertilizers by U.S. agriculture since World War II has kept food cost relatively low. However, environmental costs are associated with some of these inputs, including pollution of groundwater by agricultural chemicals. Among the sources of groundwater pollution in rural areas, agriculture is potentially the most serious long-term problem because (*a*) groundwater pollution cannot be traced readily to particular individuals or locations, and (*b*) the area vulnerable to pollution is extensive (CAST). About 50 million people rely on groundwater in areas identified as vulnerable to agricultural groundwater pollution (Lee and Nielsen).

The most common agricultural chemical pollutant is nitrogen in the form of (water-soluble) nitrates. Elevated nitrate levels in groundwater are attributed to the low relative cost of nitrogen and other chemical fertilizers and the ease with which nitrates move in soil. While few cases of death or severe illness are linked directly to agricultural contamination, the human health consequences of nitrate exposure include methemoglobinemia (blue-baby disease) in infants and gastric cancer in adults (Bower). In addition, the potential for surface water pollution from groundwater is also an important environmental concern; approximately 30% of surface water streamflow is from groundwater sources (Saliba).

Public concern over the potential health consequences of groundwater pollution is motivating the U.S. Environmental Protection Agency (EPA) and state environmental agencies to intensify regulatory activities in the area of nonpoint pollution. Regulatory options to reduce nonpoint pollution imply a range of costs for agricultural producers. For example, reduction of nitrate leaching requires modification of farmers' management practices that, in turn, may lead to reduced profits. Regulations that require major reductions in nitrate groundwater pollution may result in significant shifts in crop production between regions of the United States, possibly increasing food costs for consumers. On the other hand, elimination of nitrate pollution may be possible in some regions with relatively little effect on farm profits and consumer costs if producers have a range of alternative management practices and crops from which to choose. Quantification of these potential economic and environmental tradeoffs is important information in the societal debate on this issue.

The reseach reported here builds upon the conceptual and empirical approaches found in some existing studies to develop a bioeconomic

Scott L. Johnson is an economist, South Coast Air Quality Management District, and former graduate student, Oregon State University; Richard M. Adams and Gregory M. Perry are, respectively, a professor and an associate professor, Department of Agricultural and Resource Economics, Oregon State University.

Technical Paper No. 9435 of the Oregon Agricultural Experiment Station.

The research described in this paper was partially supported by the U.S. Geological Survey under USGS award number 14-0300001-G1486 to Oregon State University. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

The authors gratefully acknowledge the assistance of Bob Berrans in data collection and the helpful comments of Bob Taylor on an earlier draft of this manuscript.

analysis of agricultural groundwater pollution. The overall objective is to assess the on-farm economic effects of strategies to reduce nitrate groundwater pollution. The assessment reflects the linkages between producer behavior (management practices), crop yields, and groundwater pollution by integrating plant simulation, hydrologic, and economic models of farm-level processes. Using this framework, the analysis (*a*) identifies possible changes in farm management and farm income to meet reductions in nitrate leachate and (*b*) evaluates the effectiveness of input restrictions and taxes commonly proposed as solutions to groundwater pollution.

Related Literature

The economic and policy issues in regulating agricultural nonpoint pollution are well documented. For example, the conceptual dimensions of nonpoint pollution are developed in Langham, Sharp and Bromley, and Griffin and Bromley. Within the last five years, additional theoretical evaluations of nonpoint pollution regulatory issues are found in Saliba, Shortle and Dunn, Milon, and Segerson.

In practice, regulations often focus on definition and implementation of "best management practices" (BMPs). Assessing the benefits and costs of changes aimed at controlling nonpoint pollution from agriculture is difficult because of the complex linkages between the physical and economic environment. However, an understanding of these biophysical processes is critical to the performance of empirical economic analyses.

A number of economic studies have included the hydrological/biophysical aspects of nonpoint pollution. Early examples are found in Jacobs and Casler and Park and Shabman. Other examples include Anderson, Opaluch, and Sullivan and Gardner and Young. Anderson, Opaluch, and Sullivan specifically note the substantial informational requirements of linking nonpoint agricultural pollution of groundwater to actual management policies and economic impacts. Additional analyses concerning economic "targeting" of nonpoint pollution abatement and optimal spatial management are found in Braden, Hericks, and Larson and in Bouzaher, Braden, and Johnson.

Most empirical studies address surface water pollution. Exceptions include Gardner and Young, Stevens, and Knapp et al. For groundwater pollution, an accurate economic assessment of the biophysical processes concerning leachate requires input from several disciplines (e.g., engineering, geohydrology, plant science). The site-specific nature of nonpoint pollution events also suggests that such information be available at the farm or regional level (Stevens; Anderson, Opaluch, and Sullivan). Few empirical studies have successfully used biophysical simulation models in assessing the economic implications of groundwater quality regulations.

Study Area

The empirical focus is on nitrate groundwater pollution in a two county area of the Columbia Basin in Oregon, an important agricultural area in the Pacific Northwest. The region's climate is semi-arid, with hot, dry summers and cold winters. Mean annual precipitation is approximately nine inches, requiring irrigation for most crop production. The two counties (Umatilla and Morrow) contain 244,000 acres of irrigated land, of which 137,000 acres are irrigated using center pivot systems (Miles). The principal crops are alfalfa, potatoes, winter wheat, and field corn. Most of this production occurs on light-textured soils (208,000 acres classified as sands) (Johnson and Makinson, Hosler). Irrigated production on such soils has significant potential for nitrate groundwater pollution as attempts to keep soil moisture at near-optimum levels for physical output can result in excessive water applications and the leaching of water (and nitrates) below the root zone. The Oregon Department of Environmental Quality reports that nitrate levels in eleven of twenty-five test wells in the two-county area exceed current U.S. EPA standards (10 mg N/l), with some nitrate concentrations as high as 80 milligrams N/l (Pettit).

Farms in the study area are highly capitalized and intensively managed. For example, the effectiveness of water and fertilizer application rates on potato growth is monitored weekly via infrared aerial photography, petiole sampling, and other advanced techniques. Fertilizer input levels and yields are high; for potatoes, total fertilizer applications typically range from 675 to 900 kilograms per hectare, of which 60% or more is nitrogen. Application of fertilizers and water are controlled primarily through center pivot sprinkler irrigation systems ("fertigation").

While the empirical results generated here will not exactly represent adjustment costs in other agricultural areas, they can suggest (*a*) the im-

portance and feasibility of modeling accurately the biophysical aspects of agricultural nonpoint pollution and (*b*) the magnitude and costs of leachate reductions achievable under intensely managed systems.

Methodology

The integrated approach used in this analysis includes the linking of (*a*) a plant simulation model to predict crop yields under different input levels, (*b*) a dynamic optimization model to optimize irrigation and fertilization decisions for each crop, and (*c*) a linear programming model to assess rotational (crop mix) implications for a representative farm in the study area. Each of these component models is discussed in this section.

The crop simulator is from the CERES family of plant simulation models (Ritchie, Godwin, and Otter-Nacke; Hodges et al., Jones and Kiniry). CERES models account for water and fertilizer use by a crop, amounts of water and fertilizer leached throughout the season, and resulting yield. CERES models for potatoes, corn, and wheat are adapted for use in the study area.[1] These crops account for 80% of crop acreage in the study area.

The CERES models estimate daily potential photosynthesis based on weather, accumulated biomass, leaf area, and genetics; CERES then uses water and (or) nitrogen stress estimates to calculate actual photosynthesis. Treatment of water and nitrogen balances in CERES are somewhat asymmetric, i.e., insufficient water and (or) nitrogen will inhibit plant growth, thereby reducing final yield, but water and nitrogen applications in excess of optimal levels generally do not inhibit yields. Most of CERES's stress calculations are based on a form of the law of the minimum, expressed as

$$(1) \qquad B = \text{Min}\,(f(Sa), f(N), M),$$

where B is biomass from a single days growth, $f(Sa)$ is the maximum biomass as imposed by soil moisture levels, $f(N)$ is the maximum biomass under a given soil nitrogen level, and M is the maximum biomass imposed by other factors such as weather and genetics (Waggoner and Norvell; Lanzer, Paris, and Williams).

In addition to the plant growth simulator, the CERES models include routines to estimate soil water and nitrogen balances. These routines simulate the vertical movement of water and nitrates between layers of the root zone as well as other aspects of the nitrogen cycle. Together, the routines provide daily predictions of water and nitrate movement out of the root zone into the vadose zone. The topsoil and vadose layers in the study area are predominantly sands or other light textured soils, allowing relatively free movement of water into the aquifer.

The second component of the assessment framework is a two-state variable dynamic optimization model for scheduling irrigation and fertilization decisions for each crop. Although a forward recursive dynamic algorithm is used in the solution process, the model formulation is conceptually similar to that of the open-loop stochastic control model used in Zavaleta, Lacewell, and Taylor. The dynamic optimization model determines daily water and nitrogen applications to maximize per acre returns above variable costs, subject to restrictions imposed on the system. The dynamic optimization model utilizes the CERES crop simulator to predict yields and returns from different irrigation and fertilization strategies. The model identifies an optimal irrigation and fertilization strategy by considering returns less water and nitrogen costs.

The third component in the assessment is a farm-level linear programming (LP) model. This component is used to examine shifts in crop mix on a representative farm that may result from restrictions on overall nitrate leachate levels. The farm represents the economic, cultural, soil, and other conditions typically found in the area, including the high level of technology currently used in potato production. The technical coefficients linking nitrogen, water use, and yields in the LP model are taken from the optimal solutions obtained by the dynamic optimization model.

Linking the Models

The output from the CERES plant simulation models is used as input in the dynamic optimization models (in the form of the transition relations). The outputs from the dynamic optimization model, such as yields, nitrogen, and water use and associated leachates for various regulatory options are then placed in a whole-farm context via the LP model. The optimization model is discussed below to clarify these linkages.

The general dynamic optimization problem can be represented by the following equations:

[1] A CERES model for alfalfa, the other major crop in the study area, was not available.

$$(2)\quad R(f(t), w(t), V(t), P, t) = \max_{w \leftarrow W,\, f \leftarrow F} \{MR_t(w(t), f(t), Sa(t), Ntr(t), P, V(t), t) + R(f(t-1), w(t-1), V(t-1), P, t-1)\},$$

$$(3)\quad MR_t(\cdot) = MY(Sa(t), Ntr(t), V(t), t)(Py - Ch) - f(t)Pf - df(t)Lf - w(t)Pw - dw(t)Lw,$$

$$(4)\quad bf(t) = 0 \text{ for } f(t) = 0; \quad = 1 \text{ otherwise,}$$

$$(5)\quad bw(t) = 0 \text{ for } w(t) = 0; \quad = 1 \text{ otherwise,}$$

$$(6)\quad Ntr(t+1) = K(f(t), Ntr(t), V(t), t),$$

$$(7)\quad Sa(t+1) = I(w(t), Sa(t), V(t), t),$$

$$(8)\quad Sa(0) = Sa_0,$$

$$(9)\quad Ntr(0) = Ntr_0,$$

$$(10)\quad LL \le Sa(t) \le Sat \; t = 0,1, \ldots, T,$$

$$(11)\quad Nmin \le Ntr(t) \le Nmax \; t = 0,1, \ldots, T,$$

$$(12)\quad Wmin * bw(t) \le w(t) \le Pc(t) \; t = 0,1, \ldots, T,$$

$$(13)\quad 0 \le f(0) \le Mxf, \text{ and}$$

$$(14)\quad Fmin * bf(t) \le f(t) \le c * w(t) \; t = 1,2, \ldots, t.$$

Equation (2) provides the basic forward recursion relationship for the dynamic optimization algorithm. Using this relationship, the producer is maximizing a before-tax-net-return function for a given hectare [R] with respect to the two decision variables, irrigation [$w(t)$] and fertilizer [$f(t)$] quantities, two state variables, soil moisture [$Sa(t)$] and nitrogen [$Ntr(t)$], exogenous random factors [$V(t)$], and input and output prices [P]. The net return function is the cumulative sum of the daily marginal return functions [$MR_t(\cdot)$] up to and including stage t. The marginal return function (3) is defined by the marginal yield function (the incremental change in yields) when moving between stages [$MY(\cdot)$], the output price [Py], variable harvest cost [Ch], water [Pw] and fertilizer [Pf] costs, and fixed irrigation [Lw] and fertilizer [Lf] costs. Equations (4) and (5) define binary variables used to indicate if any irrigation [$bw(t)$] or fertilization [$bf(t)$] has occurred on a given day. All costs incurred up to the first decision period (such as land, capital, and planting costs) are fixed. Only variable costs associated with irrigation and fertilization activities affect the decision set. The model uses 1988 price and cost data.[2]

Equations (6) and (7) define the transition functions from one stage and state to the next stage for both soil moisture [$Sa(t)$] and nitrogen [$Ntr(t)$], as predicted by CERES. Equations (8) and (9) provide the initial conditions for the state variables. Equations (10) through (14) define the constraints and boundary conditions for the decision and state variables. Specifically, equations (10) and (11) define the boundary conditions for the state space at time t, with LL and Sat the lower and upper limits on soil moisture and $Nmin$ and $Nmax$ the lower and upper limits on soil nitrogen, respectively. Equations (12) through (14) provide the possible decision space at time t. These equations restrict irrigation and fertilization decisions to be either zero or above some minimum amount ([$Wmin$] and [$Fmin$]) and restrict the irrigation and fertilization amounts to be less than or equal to specified levels.[3] Equation (12) ensures that irrigation quantities do not exceed pumping capacity ($Pc(t)$), (13) restricts preplant fertilizer to some maximum rate based on toxicity, and (14) requires that fertilizer applied after planting not exceed a fixed proportion (concentration) of water applied in the same period.

[2] The output prices (less per unit harvesting and marketing variable costs) are \$0.074, \$0.16, and \$0.11 per kilogram of potatoes, winter wheat, and field corn. The costs of irrigation water and nitrogen fertilizer were \$0.16 per hectare-millimeter and \$0.34 per kilogram, respectively.

[3] This integer constraint (of requiring a minimum amount of irrigation if irrigation quantity is greater than zero) is based on physical limits on the equipment (e.g., maximum speed of the circles) and the fact that farmers will not make applications of water or nitrogen less than some minimum level.

This formulation of a producer's seasonal decision problem is based on a dynamic programming [DP] solution algorithm; however, it does not have all of the desirable properties of DP. First, DP assumes that the marginal product derived from moving from one state and stage to another state in the next stage is invariant to the path taken to reach that state. In the formulation used here, that assumption does not hold. Second, CERES provides only the final yields from a given irrigation and fertilization pattern. Therefore, marginal (incremental) yields must be inferred through comparison of final yields of feasible states. As a result, the dynamic optimization model does not yield solutions that are (necessarily) globally optimal.

Producer Behavioral Considerations

An important requirement in this assessment is to portray accurately the irrigation and fertilization decisions faced by farmers. On the surface, it appears that farmers using irrigation could eliminate the majority of nitrate leachate by more careful management of nitrogen and water applications. However, farmers in the study area confront a complex problem which includes uncertainty in upcoming weather events, periods of high evapotranspiration, limited pumping capacity, and heterogeneity in the physical environment. These factors contribute to nitrate pollution under irrigated conditions and thus need to be considered in a modeling approach.

Leaching will not occur unless soil moisture levels exceed field capacity. Imperfect knowledge about soil moisture levels in the crop root zone at the time of the irrigation decision may result in excessive application of water. Similarly, imperfect knowledge about soil fertility levels may result in excess nitrogen applications. In formulating the optimization model, however, it is assumed that farmers know with certainty the current fertility and moisture states of their fields. While a strong assumption for grain crops, most potato farmers in the area monitor fertility and moisture levels with the intensity assumed here.

Even with knowledge about current nitrogen and moisture levels, uncertainty concerning future events may result in leaching. For example, a heavy rain immediately after irrigation can cause leaching. Changes in temperature, wind, and other climate variables can also change irrigation efficiency, resulting in too much or too little water entering the soil profile. Soil heterogeneity can cause nitrate leaching; i.e., a field that is relatively homogenous in soil type may still have substantial variability in water holding capacity. Thus, a farmer who irrigates to ensure that the most drought-prone part of a field is never stressed will overwater the rest of that field.

Several features are included in the optimization model to address these issues. Irrigation and fertilizer decisions are made each day based on expected, rather than actual, weather throughout the remainder of the growing season, but final outcomes of the decisions reflect actual weather. The use of expected weather is necessary because the CERES models require weather data for the entire growing season to compute yields from a given irrigation pattern. Irrigation efficiency is treated as a normally distributed random variable with the optimization model using expected efficiency when making decisions. To simulate potential soil heterogeneity, routines were added to CERES to allow for subfields (with distinct soils and yields) receiving the same management strategies. Decisions are based on the weighted average of these subfields.

Optimal fertilization and irrigation rates are compared to actual producer fertilizer and irrigation data to suggest the extent to which producers are overapplying nitrogen or water. The subsequent empirical analyses are based on actual producers' practices within the study area. Specifically, actual field data on fertilizer rates and frequencies, irrigation schedules, yields, and soil nitrate levels were used to establish base model conditions for each crop.

Modeling Crop Rotation

The LP model used in this study is a standard crop mix model similar to that formulated by El-Nazer and McCarl. As noted by El-Nazer and McCarl, the only factors restricting cropping choices in this area are land and rotational considerations. The high profitability of potatoes encourages producers to structure farm capital so as not to restrict production choices. In addition, the long growing season and low rainfall tend to minimize timing restrictions.

The LP formulation includes basic federal farm program provisions including acreage set-asides and deficiency payments. The model's objective is to find the optimal crop mix within the context of various constraints on farm-level nitrate pollution rates. It is assumed that base acreage for government programs does not limit acreage planted to any program crop.

The LP is restricted to seven rotation strate-

Table 1. Simulated Nitrogen, Water, Yield and Profit Levels, by Crop

Crop/Analysis	Pred. Yield	Profit	Application Water	Application Nitrogen	Leachate Water	Leachate NO₃	Change in Profits
	(kg/ha)	($/ha)	(mm/ha)	(kg/ha)	(mm/ha)	(kg/ha)	($/ha)
Wheat							
Current practices	8,779 [9,076]	1,207	605	298	66	1.53	
Optimal solution:							
w/Shano Silt	9,176	1,280	394	303	11	0.92	73
w/Quincy Sand	9,102	1,253	531	280	45	3.17	46
w/25% N reduction	8,156	1,128	531	210	50	3.44	−79
w/N tax	8,603	1,107	468	244	10	1.00	−173
w/pollution tax	8,870	1,208	485	260	10	1.00	−72
Field corn							
Current practices	11,424 [11,460]	1,010	720	320	42	2.37	
Optimal solution:							
w/Shano Silt	12,019	1,100	456	383	0	0.00	90
w/Quincy Sand	11,992	1,067	605	391	24	2.07	57
w/25% N reduction	10,342	858	605	293	25	1.98	−152
w/N tax	12,004	929	613	382	45	3.71	−81
w/pollution tax	11,987	1,049	636	392	9	0.81	−39
Potatoes							
Current practices	58,900 [58,986]	4,081	711	434	18	5.11	
Optimal solution							
w/Quincy Sand	61,007	4,224	799	400	14	2.30	143
w/25% N reduction	47,504	3,262	799	300	14	2.25	−819
w/N tax	60,241	4,038	728	390	15	3.09	−186
w/pollution tax	59,798	4,120	724	407	6	1.12	−104

gies.[4] All rotations are currently practiced in the area and restrict potatoes on a given field to no more than one out of four years to minimize disease and pest problems. The dynamic optimization model provides the coefficients for water and fertilizer costs and quantities, yield, and leachate quantities for each crop in each rotation. For three of the crops, coefficients are optimal for given crop and leachate constraint levels, a characteristic that is different from most LP crop-mix models. The exception is alfalfa, for which no CERES model was available. The alfalfa yield coefficients are based on average yield data from representative farms in the region. It is assumed that no nitrates leach while a field is planted in alfalfa.

Base Case and Regulatory Options

The above methodology is used to investigate the changes in yields, profits and nitrate leachate for potatoes, winter wheat, and field corn under six fertilizer-water application situations. The six analyses reported here include (*a*) a base case that replicates the effect of current irrigation and fertilization practices on profits and leachate, (*b*) an optimal solution based on the irrigation and fertilization patterns determined by the dynamic optimization models, (*c*) an across-the-board 25% reduction in applied nitrogen for the optimal case, (*d*) a nitrate leachate constraint placed on the optimization model, (*e*) a nitrogen input tax, and (*f*) a pollution (Pigovian) tax. All solutions were generated under 1988 weather conditions for the area and expected weather as generated by a weather generator (Richardson and Wright).

Results

The results from applying the CERES-optimization models for these crops and conditions to the above input and leachate alternatives are presented in table 1. The table contains nitrogen and water applications, yields, nitrate leachate, and profits for the base case, optimal case, and

[4] The seven rotations are [wheat (w), corn (c), wheat (w), potatoes (p), alfalfa (a)]: w-c-w-p; c-a-a-a-p; w-a-a-a-p; c-a-a-a-a-p; a-a-a-p; a-a-a-a-p; and w-a-a-a-a-p.

under each regulatory scenario.[5] The base case, representing actual producer behavior, provides a benchmark against which the effects of alternative nitrogen and water application strategies can be evaluated. Because some corn and wheat in the area are grown on silty soil, the optimization models for these crops were run with both a sandy and a silty soil. The use of two soils provides information on the effect of water-holding capacity on leaching rates. The actual yield (reported by the famers sampled in the study area) for each base case is shown in brackets under predicted yields. The results of the base models for corn, wheat, and potatoes indicate current leachate levels of approximately 2.4, 1.5, and 5.1 kilograms per hectare of nitrates, respectively.

While no data on actual leachate levels exist for the study area, the leachate levels modeled under current practices were unexpectedly low for all three crops when compared with levels reported in other regions. For example, Hergert found that actual leaching rates for irrigated corn in Nebraska on sandy soil ranged from 12 to 146 kilograms of nitrogen per hectare depending on the weather year and irrigation strategy. In part, the low levels predicted in this study can be attributed to (*a*) relatively homogenous soils, (*b*) use of center pivot irrigation systems, (*c*) very few summer rainfall events, and (*d*) a high level of current irrigation and fertility management. Nonetheless, there is evidence that CERES understates absolute nitrate leachate levels under these conditions.[6] However, the relative ranking between different model solutions are assumed correct for each crop.

The first point of comparison is between the base case and the solution of the optimization model for each crop. As is evident from the table, movement to optimal timing of nitrogen and water applications resulted in less total water and slightly less total nitrogen applied, substantially less total nitrogen leachate, a slight increase in yields, and greater profits for all three crops. Thus, if the application amounts and timing predicted by the optimization model were followed under the 1988 crop year conditions, producers could, in some cases, reduce water and/or nitrogen applications, increase profits, and reduce leachate. However, the results for the optimization model are "best case" estimates for a given weather year. Alternative weather years may not yield the same outcome.

Additional optimization models were run for corn and wheat using silty soils, which are less prone to leaching. Yields and profits increase relative to production on sandy soil, while water usage and nitrate leachate decrease because it is more costly to minimize water stress and percolation on soils with low versus moderate water holding capacity.

Because of the *ex post* nature of the dynamic optimization, the optimal solutions use information about weather events that may not be available to farmers. However, movement from current management strategies closer to those identified as optimal is possible even without perfect information about future weather events. The primary change in management observed in the optimal solution is the number of fertilizer applications. Specifically, the number of nitrogen applications is typically two to three times higher under the optimal solutions than for current practices.[7] Quantities of nitrogen per application were smaller under the optimal solution. In effect, higher profits and lower nitrate leachate levels can be achieved if farmers time applications to coincide more closely with plant needs.

Restrictions on Inputs

One objective of this study is to investigate the on-farm economic effects of possible regulatory restrictions on nitrogen, water, and other inputs. To explore this type of restriction, nitrogen applications were reduced by 25% in both the current practice and optimal solutions. This case corresponds to a situation where producers reduce application levels by a fixed percentage (here 25%), but follow the same schedule recommended by the optimization model. For corn,

[5] Because of the significant computational time required to obtain an optimal solution to the two state variable dynamic optimization problem, models were solved on three different computers. The computers used for this study were a VAX 8700, a Definicon 785, and a Floating Point System 164/264. The basic dynamic optimization analyses would require approximately 30, 90, and 98 hours of computer time for wheat, potatoes, and corn if all were run on a Definicon 785. Finally, to minimize any problems with varying numeric precision, all solutions for a given crop in a given rotation were solved on the same operating system.

[6] Recent experiments with CERES for similar crops and conditions in Washington resulted in higher leachate levels (N. K. Whittlesey, Washington State University, personal communication). Given the difficulty of validating leachate routines in biophysical simulators for all possible soil-water-crop situations, the utility of such models is greatest in ranking potential leachate changes, not in predicting absolute leachate levels.

[7] The number of nitrogen applications for the current practices compared with the base optimization model was 5 vs. 10 for wheat, 6 vs. 24 for corn, 12 vs. 24 for potatoes following alfalfa, and 12 vs. 32 for potatoes following grain.

a 25% reduction decreased nitrogen leachate by approximately 4% from the optimization model. Yields were reduced about 14%, resulting in a profit loss of approximately $200 per hectare. For wheat, this nitrogen reduction increased leachate by about 9%.[8] Yields were reduced about 10%, resulting in a profit loss of approximately $125. For potatoes, the nitrogen reduction reduced leachate by about 2%. Yields were reduced about 22%, resulting in a profit reduction of over $900 per hectare. In short, imposing such a constraint on nitrogen applications under efficient timing of nitrogen and water applications imposed large costs on farmers, with little change in nitrate leachate.

To explore further the effect of nitrogen reductions, the optimization models were solved to determine the minimum level of nitrate leachate possible without terminating crop growth. While not reported in table 1, these analyses resulted in substantial reductions (above 70%) but not total elimination of leachate for all crops. These reductions were accomplished through significant reductions in water application and more moderate decreases in nitrogen applications. The analysis suggests that some level of nitrate leachate will result from the production of these crops, even under optimal management. The results also emphasize the importance of water management in an overall strategy to minimize nitrate leachate rates.

Constraints on nitrate leachate rates, by definition, assure decreases in pollution rates independent of the value of the crop. However, the optimization models indicate clear upper bounds on leachate restrictions that can be imposed on any crop. These upper bounds are determined by the number and size of rainstorms and the number of days with relatively high evapotranspiration within the growing season. For example, in the base wheat model, the minimum amount of nitrate leachate was 0.98 kilograms of nitrogen per hectare. Lower leachate rates could not be reached without killing the crop. Further, limiting leachate has little practical value because it is costly to monitor nonpoint pollution rates. Nevertheless, such limitations provide a means for defining (in general terms) the "best management practices" to achieve given target reductions in pollution rates. These preferred practices can be used to formulate regulatory guidelines for reducing nitrate leachate from high-risk soils.

Taxes

Various forms of taxes are widely suggested as a means to induce changes in farmers' behavior (Griffin and Bromley, Shortle and Dunn, Segerson, Gardner and Young, and Stevens). A simple input tax tested here involved a 100% tax on nitrogen. The tax reduced profits for wheat, corn, and potatoes by 14%, 7%, and 4%, respectively. Taxes had negligible impacts on water use in the corn model and only minor impacts on nitrogen use for the corn and potato models. Conversely, a nitrogen tax in the wheat model moderately reduced both water and fertilizer use so that a 68% reduction in nitrate levels was achieved.

The short run (within a growing season) derived-demand price elasticities for nitrogen fertilizer implied here range from −0.02 to −0.13 for the 100% price increase. Such low elasticities are expected because the price elasticity of derived demand varies directly with the share of total production cost associated with a given factor and the elasticity of substitution between a given factor and other inputs. In this case, water and nitrogen are the only variable inputs. Furthermore, the factor shares for nitrogen in the base models are small, varying from 3% to 11% of total variable costs. The low demand elasticities calculated from the modeled nitrogen use imply that high input taxes would be needed for most crops to meaningfully reduce pollution.

Taxes on leachate (Pigovian taxes) are expected to be more efficient economically than input taxes, because leachate taxes allow greater latitude in producer adjustment. To test this, a Pigovian tax based on mitigation costs was applied to each optimization model. Specifically, a tax of $26.42 per kilogram of nitrate leached into the vadose zone was used, based on estimated costs to remove nitrates from drinking water (Walker and Hoehn). This leachate tax results in slight to moderate reductions in profits ranging from 3% to 6% compared to the base optimization model. However, this leachate tax reduces leachate levels more than the 100% input tax. The exception is wheat, where the leachate levels under each tax are similar (because the leachate level in the input tax analysis was already within a few % of the minimum leachate level). As expected, the Pigovian tax analyses had higher profits than the direct nitrogen tax analysis.

[8] The simulated increase in leachate rates occurred because the early season nitrogen stress limited the ability of the plant to use nitrogen later in the season, increasing the opportunities for mineralized nitrogen to leach.

Table 2. Effects of N Leachate Restrictions on Crop Mix

Analysis	Net Returns ($)	Nitrate Leachate	Shadow price N Leachate	Crop Mix: Potato (Grain)	Potato	Wheat	Corn	Alfalfa	Idlement
		(Kg/N)	($/Kg)	(hectares)					
Base	523,000	1,526			190	267	152		141
750 kg N leachate	485,000	750	67		190	276	152[a]		141
500 kg N leachate	447,000	500	220		190	276[a]	152[a]		141
250 kg N leachate	372,000	250	449	43[a]	147[a]	214[a]	118[a]	129	105

[a] Acreage receives reduced N and/or water to achieve N restriction.

Like restrictions on leachate, Pigovian taxes have limited practical value because of the costs required to monitor actual pollution rates for each farm (Segerson). Leachate taxes would also impose added farm management costs related to basing input decisions on complex pollution forecasting models (Shortle and Dunn). However, analysis of Pigovian taxes is useful for forming socially optimal pollution goals and in generating irrigation and fertilization strategies, assuming the tax levels roughly approximate the true marginal social cost of nitrate pollution.

Whole-Farm Effects

The results of the farm-level LP model reported in table 2 suggest that the wheat-corn-wheat-potato rotation is the profit-maximizing long-run equilibrium solution when no leachate restrictions are imposed. Such a rotation is similar to that currently practiced in the study area. For the 750-hectare representative farm, the rotation results in an annual average nitrate leachate rate of 1,525 kilograms of nitrogen. A leachate restriction of approximately 50% (750 kg) is achieved without crop mix changes through reductions in nitrogen and water applications to corn. As more restrictive total leachate constraints are imposed, the model shifts toward production activities that restrict leachate in both corn and wheat. Further restrictions cause the model to select activities that restrict leachate in potatoes. Finally, the model shifts to a potato-alfalfa-alfalfa-alfalfa rotation. The costs of these restrictions (reduced profits) increase at an increasing rate, as reflected in the shadow price of leachate. For example, to achieve the last 250-kilogram reduction imposes a profit penalty of $75,000, whereas the profit penalty for the first 750-kilogram reduction was only $38,000.

This analysis indicates that the lowest cost method of reducing pollution across a whole farm in the study area is to restrict nitrate pollution on grain fields; the profits gained in potato production by allowing an additional kilogram of nitrogen leachate are much larger than when an additional kilogram of nitrogen leaches under corn or wheat production. Moreover, as the nitrate constraint becomes more restrictive, land rents fall significantly because of reduced profits arising from the restrictions on pollution and shifts in crop rotations. These whole-farm results are obtained under optimal timing of nitrogen and fertilizer applications; the cost of potential leachate reductions could be higher if measured against different management intensities.

Conclusions

These analyses, for intensively managed, irrigated conditions on fields with low to moderate water-holding capacities, suggest some nitrogen leachate reductions can be accomplished with little loss in profits. Specifically, by changing the timing and application rates of nitrogen and water, profits for some crops increase while reducing total nitrogen application levels and resultant leachate. However, once these efficiencies are obtained, further reductions in nitrate leachate bring increasing costs to producers. Crop mixes as modeled here are relatively insensitive to most taxes and regulations, given the need to maintain at least one high-value crop (potatoes) in the rotation.

These results are based on specific fields for well-managed, highly capitalized farms. They

do not necessarily reflect management decisions or field conditions of other producers of irrigated crops. The leachate and profit benefits of improved irrigation and fertilizer scheduling may be greater for farms with alternative irrigation systems. Conversely, if producers are already managing intensely their water and fertilizer applications, leachate reductions may not be achievable without profit penalties. This analysis is also representative of only three crops and does not address the affect of different irrigation technologies or climates on optimal fertilization strategies. However, the integrated methodology does reflect the relationships between producer behavior and the physical and biological dimensions of groundwater pollution. Such an integrated approach would appear critical to understanding the economics of nonpoint pollution control in other agricultural settings.

[Received April 1990; final revision received November 1990.]

References

Anderson, G. D., J. J. Opaluch, and W. M. Sullivan. "Nonpoint Agricultural Pollution: Pesticide Contamination of Groundwater Supplies." *Amer. J. Agr. Econ.* 67(1985)1238–43.

Bouzaher, A., J. B. Braden, and G. V. Johnson. "A Dynamic Programming Approach to a Class of Nonpoint Source Pollution Control Problems." *Manage. Sci.* 36(1990):1–15.

Bower, H. *Groundwater Hydrology*. New York: McGraw-Hill Book Co., 1978.

Braden, J. B., E. E. Herricks, and R. S. Larson. "Economic Targeting of Nonpoint Pollution Abatement for Fish Habitat Protection." *Water Resour. Res.* 25(1989):2399–2405.

Braden, J. B., G. V. Johnson, A. Bouzaher, and D. Miltz. "Optimal Spatial Management of Agricultural Pollution." *Amer. J. Agr. Econ.* 71(1989):404–13.

Council for Agricultural Science and Technology (CAST). *Agricultural and Groundwater Quality*. CAST Rep. No. 103. Ames IA, 1985.

Edwards, S. F. "Option Prices for Groundwater Protection." *J. Environ. Econ. and Manage.* 15(1988):475–87.

El-Nazer, T., and B. A. McCarl. "The Choice of Crop Rotation: A Modeling Approach and Case Study." *Amer. J. Agr. Econ.* 68(1986):127–36.

Gardner, R. L., and R. A. Young. "Assessing Strategies for Control of Irrigation-Induced Salinity in the Upper Colorado River Basin." *Amer. J. Agr. Econ.* 70(1988):37–49.

Griffin, R. C., and D. W. Bromley. "Agricultural Runoff as a Nonpoint Externality: A Theoretical Development." *Amer. J. Agr. Econ.* 64(1982):547–52.

Hergert, G. W. "Nitrate Leaching through Sandy Soil as Affected by Sprinkler Irrigation Management." *J. Environ. Quality* 15(1986):272–78.

Hodges, T., T. Mogusson, S. L. Johnson, and B. Johnson. *Substor Potato Model*. FORTRAN program, 1989.

Hosler, R. E. *Soil Survey of Morrow County Area, Oregon*. Washington DC: U.S. Department of Agriculture, Soil Conservation Service, 1983.

Jacobs, J. J., and G. L. Casler. "Internalizing Externalities of Phosphorous Discharges from Crop Production to Surface Water: Effluent Taxes Versus Uniform Restrictions." *Amer. J. Agr. Econ.* 61(1979):309–72.

Johnson, D. R., and A. J. Makinson. *Soil Survey of Umatilla County Area, Oregon*. Washington DC: U.S. Department of Agriculture, Soil Conservation Service, 1988.

Jones, C. A., and J. R. Kiniry. *CERES-Maize: A Simulation Model of Growth and Development*. College Station TX: Texas A&M University Press, 1986.

Knapp, K. C., B. K. Stevens, J. Letey, and J. D. Oster. "A Dynamic Optimization Model for Irrigation Investment and Management Under Limited Drainage Conditions." *Water Resour. Res.* 26(1990):1335–43.

Langham, M. R. "Theory of the Firm and the Management of Residuals." *Amer. J. Agr. Econ.* 54(1972):315–25.

Lanzer, E. A., Q. Paris, and W. A. Williams. *A Nonsubstitution Dynamic Model for Optimal Fertilizer Recommendations*. Davis CA: Giannini Foundation, 1987.

Lee, L. K., and G. Nielsen. "Groundwater: Is It Safe to Drink?" *CHOICES*, no. 3 (1988), pp. 4–7.

Miles, S. D. "Oregon Irrigated Acres, 1987." Dep. Agr. and Resour. Econ., Oregon State University, 1987.

Milon, J. W. "Interdependent Risk and Institutional Coordination for Nonpoint Externalities in Groundwater." *Amer. J. Agr. Econ.* 68(1986):1229–33.

Nielsen, E. G., and L. K. Lee. *The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals*. Washington DC: U.S. Department of Agriculture, Economic Reseach Service, 1987.

Park, W. M., and L. A. Shabman. "Distributional Constraints on Acceptance of Nonpoint Pollution Controls." *Amer. J. Agr. Econ.* 64(1982):455–62.

Pettit, G. "Assessment of Oregon's Groundwater for Agricultural Chemicals." Dep. Environ. Quality, State of Oregon, 1988.

Richardson, C. W., and D. A. Wright. *WGEN: A Model for Generating Daily Weather Variables*. Washington DC: U.S. Department of Agriculture, Agricultural Research Service, 1984.

Ritchie, J. T., D. C. Godwin, and S. Otter-Nacke. *CERES-Wheat: A Simulation Model of Wheat Growth and Development*, 1985.

Saliba, B. C. "Irrigated Agricultural and Groundwater Quality—A Framework for Policy Development." *Amer. J. Agr. Econ.* 67(1985):1231–37.

Segerson, K. "Uncertainty and Incentives for Nonpoint Pollution Control." *J. Environ. Econ. and Manage.* 15(1988):88–98.

Sharp, B. M. H., and D. W. Bromley. "Agricultural Pollution: The Economics of Coordination." *Amer. J. Agr. Econ* 61(1979):591–600.

Shortle, J. S., and J. W. Dunn. "The Relative Efficiency of Agricultural Source Water Pollution Control Policies." *Amer. J. Agr. Econ.* 68(1986):668–77.

Stevens, B. K. "Fiscal Implications of Effluent Charges and Input Taxes." *J. Environ. Econ. and Manage.* 15(1988):285–96.

Waggoner, P. E., and W. A. Norvell. "Fitting the Law of the Minimum Applications and Crop Yields." *Agronomy J.* 71(1979):352–54.

Walker, D. R., and J. P. Hoehn. "Rural Water Supply and the Economic Cost of Groundwater Contamination: the Case of Nitrates." Dep. Agr. Econ. Staff Pap. No. 88-67, Michigan State University, July 1988.

Zavaleta, L. R., R. D. Lacewell, and C. R. Taylor. "Open-loop Stochastic Control of Grain Sorghum, Irrigation Levels, and Timing." *Amer. J. Agr. Econ.* 62(1980):785–92.

Public Regulation of Agricultural Biotechnology Field Tests: Economic Implications of Alternative Approaches

Bruce A. Larson and Mary K. Knudson

Federal oversight of agricultural biotechnology field testing is based on public concerns that unknown consequences could arise from such tests, and that firms may not adequately consider the public consequences of their research and development activities. In this paper, four general types of *ex ante* and *ex post* approaches to manage public risks from field testing are explored. The analysis shows that the approaches are least effective at facilitating the research process yet controlling public risks when the research firm is small in size and potential damages exceed the value of the firm.

Key words: biotechnology, environmental bond, field tests, liability, standards.

The Food Security Act of 1985 authorized the secretary of agriculture to establish "appropriate" controls over the development and use of biotechnology in agriculture. Since that time, the U.S. Department of Agriculture (USDA) in conjunction with other federal agencies, university officials, and private industry have attempted to define "appropriate" controls and procedures for their implementation. The need for such controls was based on public concerns that unknown consequences or hazards could arise from such tests and that private firms may not adequately consider the public consequences of their research and development activities. For example, genetically altered microbes could escape from containment facilities of a field test and cause unexpected harm to nearby fields. Modified crops with new specific traits, such as herbicide resistance, drought resistance, or pest resistance, could develp weedy cousins that take over local ecosystems and increase control costs.

Based on the National Institute of Health's "Guidelines for Research Involving Recombinant DNA Molecules" (NIH), the Office of Science Technology and Policy published the "Coordinated Framework for Regulation of Biotechnology" (OSTP). The "Coordinated Framework," which outlines the federal plan for regulating uses of biotechnology, was intended to provide guidance to researchers for the safe development of biotechnology. The "Coordinated Framework" generally identified permits that may be needed from various agencies to conduct biotechnology experiments. The main agencies responsible for agricultural technologies are the USDA's Animal and Plant Health Inspection Service (APHIS), through various regulations for plant pests and animal biologics, and the Environmental Protection Agency, through the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA). However, the "Coordinated Framework" focused on laboratory testing while virtually ignoring field testing (OAB March 1990).

The USDA Office of Agricultural Biotechnology (OAB) has also proposed the voluntary "Guidelines for Research Outside the Laboratory Involving Biotechnology," which apply to institutions receiving any USDA support for research with genetically modified organisms (OAB 21 May 1990). While OAB recommendations under the guidelines are not binding on an in-

---

Bruce A. Larson is an economist in the Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Mary K. Knudson is an economist with the Institute of Public Policy Studies, University of Michigan.

The views expressed in this paper are the authors' and do not necessarily reflect the views or policies of the Economic Research Service.

The authors wish to thank, without implicating, Kathleen Segerson, Richard Ready, and an anonymous *Journal* referee for helpful comments and suggestions.

stitution or a private company, ignoring the OAB's recommendations might increase the company's liability if something were to go wrong with the experiment. Conversely, if an institution or company follows OAB recommendations, "those extra steps could be seen as 'reasonably prudent' should an unforeseen negative consequence result from the actual field trial" (OAB March 1990, p. 6).

Despite federal efforts, however, a unified approach for regulating field testing that involves biotechnology has not been developed. It also remains unclear how companies will gain approval to market some products produced using modern methods of biotechnology. As a result, some companies have decided to avoid using such methods in product development (Crawford). A consistent and coordinated regulatory environment is necessary to reduce costs and uncertainty associated with the regulatory environment while assuring adequate protection for the environment and human health (GAO, NRC).

The primary purpose of this paper is to explore how different policies alter the choice problem of the firm and influence the allocation of funds to existing and new research and development activities. In theory, and ignoring transaction costs, a Coasian-type bargaining arrangement between biotechnology researchers and local groups could be developed to determine a technology regulation policy (Coase). Of course, such bargaining can take place only after an initial assignment of property rights (Demsetz). Thus, the analysis in this paper, which analyzes the implications of the initial assignment of rights, is logically prior to such bargaining; and the type of policies for regulating biotechnological research and development will influence any later bargaining attempts. In practice, biotechnology companies are concerned that each state will establish separate policies (Crawford). A federal policy on biotechnology field testing coordinated with state agencies would probably reduce costs in the regulatory oversight process, both to firms and regulatory agencies, and provide consistent signals for research across locations.[1]

The approach in this paper follows the literature on *ex ante* regulation and *ex post* liability (Johnson and Ulen; Rizzo; Segerson; Shavell 1987, 1984a, b, 1980; White and Wittman). Focusing specifically on the case of unilateral accidents, where only the firm's behavior affects risks, we analyze how four different approaches—a fixed-cost regulatory standard, a marginal-cost standard, a property rule, and a strict-liability rule—influence the allocation of funds to research and safety activities.

Background and Model Assumptions

Much of environmental economics and the integration of law and economics is devoted to studying the appropriate means of regulating potentially hazardous activities. Following Weitzman, the "prices versus quantity" literature analyzed two general types of *ex ante* policies for controlling stochastic externalities: a marginal pollution tax on firm choices equal to the expected marginal social damage or a constraint on firm pollution equal to the expected social optimum (Fishelson; Watson and Ridker; White and Wittman; Yohe 1976, 1978). In the end, either approach could be preferred, depending on the shape of the expected benefit and cost functions.

Recognizing the stochastic and sequential nature of many externalities, another group of articles has analyzed the use of *ex ante* regulation and *ex post* liability to induce firms to internalize environmental risks (Johnson and Ulen; Rizzo; Segerson; Shavell 1987, 1984a,b, 1980; White and Wittman). For example, under a regulatory standard, a firm must comply with the standard—spend a certain amount on "safety"—before conducting an activity. Under strict liability for damages, the firm fully compensates injured parties if an accident occurs and if it can be shown that the firm's actions caused the damages. A negligence rule is another approach, where the firm may not be held responsible for any damages if it follows stipulated standards or guidelines (Kahan). Characteristic of the literature on liability is that either safety decisions of the firm are assumed to be separable from its main economic activities (Johnson and Ulen, Segerson, Shavell 1984a, Tietenberg) or the firm is assumed to earn risk-free returns from a single activity (Shavell 1987, 1980).

In contrast to existing studies, we explicitly consider the economic incentives of a firm with the opportunity to engage in a new research activity, such as field testing of crops produced using modern biotechnology methods. Thus, we analyze the case where (*a*) safety decisions are

[1] For example, since Monterey County, California, passed an ordinance requiring a full environmental review and permit for field testing in 1986, no applications have been filed, and field testing occurs elsewhere.

not separable from the main activities of the firm, (*b*) the firm engages in a riskless existing activity and a risky new activity, and (*c*) the firm has a fixed amount of initial wealth or research budget at its disposal. While a simplification, the case analyzed here captures the decision problem facing research and development (R&D) firms in the biotechnology industry. In general, R&D firms engage in multiple projects. While some R&D projects, such as further development of existing products, may offer relatively certain returns and pose little risk, more basic research may be much more uncertain.[2] On the other hand, the risks of harm associated with applied field testing of new crop varieties developed with modern biotechnology methods are considered more risky than varieties created through traditional breeding methods.

The allocation of firm wealth among existing and new research activities is a portfolio allocation problem. For example, consider a research and development firm with initial assets (or research budget) of $x > 0$ that has the opportunity to conduct a riskless and risky activity. The riskless activity earns a constant marginal rate of return of r on each dollar with no possibility of external damages. Field testing of traditional varieties or a riskless financial asset are examples of riskless activities. The risky activity, which involves field testing of a new product developed with biotechnology methods, earns a reward equal to B with a probability of success $p(\bullet)$, where $p(\bullet)$ is an increasing and concave function of firm assets allocated to the risky activity.[3] The risky activity can also cause damage outside the firm equal to h with probability $d(\bullet)$, where $d(\bullet)$ is an increasing and convex function of firm assets allocated to Activity 2.[4] Modeling uncertainty in the research process and the externality process as independent Bernoulli distributions with parameters $p(\bullet)$ and $d(\bullet)$ provides enough generality while retaining clear implications of the model. Such assumptions are common (Shavell 1984a, Tietenberg).

[2] Randomness in benefits and externalities is common to many industries, not just biotechnology R&D because of biological or geological uncertainties (e.g., the spatial distribution of mineral reserves and animal populations) and weather.

[3] While we will use the term "risky" activity, the probability distributions may not be known with certainty, and, therefore, the model could involve decision making under uncertainty or risk.

[4] Because h is constant and $d(\bullet)$ depends only on firm actions, only the incentives for safety or precaution of the firm are considered. Thus, injured parties cannot take precautionary actions to reduce the level of harm.

The structure of the model develped here is a straight forward generalization of existing models that focus on minimizing the cost of safety precautions for the risk-neutral firm (Shavell 1984a, Johnson and Ulen, and Tietenberg). However, the model is specifically designed to illustrate how a firm with the opportunity to conduct a particular research project responds to different regulatory approaches. Of course, because the cost of various R&D programs vary widely, different size firms will generally select from a different set of projects.

While the probability functions $p(\bullet)$ and $d(\bullet)$ depend only on the amount of money allocated to the risky activity, the probability functions could be written more generally as $p(\mu_1 x)$ and $d(\mu_1 x, \mu_2 x)$, where μ_1 is the percentage of assets allocated to the risky activity, μ_2 is the percentage of assets allocated to safety activities, and $1 - \mu_1 - \mu_2$ is allocated to the riskless activity. The function $d(\bullet)$ would be increasing in μ_1 and decreasing in μ_2, with $d(\bullet)$ convex. For some problems, safety activities may impede the productivity of the resources allocated to the risky activity, or a reduction in potential damage can be obtained only by using a different and less productive technology. In such cases, the probability of success could also be written as $p(\mu_1, \mu_2)$, where $p(\bullet)$ is increasing in μ_1, nonincreasing in μ_2, and concave. To clarify the analysis without changing its basic qualitative nature, it is assumed that resources allocated to safety activities substitute for resources allocated to the risky activity in the probability of damage function $d(\bullet)$. Thus, the firm implicitly chooses $\mu_2 = 0$ and controls the probability of damage through the allocation of resources to the risky activity. For example, easy substitution in the probability of damage function occurs in biotechnology field testing: the size of the experiment can be reduced, but containment facilities and other safety activities can also be reduced, leaving the probability of damage relatively constant.

In the absence of regulations, a firm has no incentive to internalize the possibility of damage from its actions into the decision-making process. Assuming the firm allocates wealth between the riskless and risky activities to maximize expected profits, the firm's problem becomes

$$(1) \qquad \max_{0 \le \mu \le 1} \; (1 + r)(1 - \mu)x + p(\mu x)B,$$

where the first term in (1) is income from the

riskless activity and the second term is the expected return from the risky activity.

Assuming an interior solution, the first-order condition for expected profit maximization can be rearranged to yield

(2) $$(1 + r) = p'(\mu^f x)B,$$

where $\mu^f \equiv \mu^f(1 + r, x, B)$ is the firm's optimal percentage of assets allocated to the risky activity, which is decreasing in $1 + r$ and x and increasing in B. Concavity of $p(\bullet)$ ensures second-order conditions for a maximum are satisfied at an interior solution. Equation (2) has the usual interpretation that the firm equates the marginal rate of return for the riskless activity to the marginal expected benefits for the risky activity. A corner solution $\mu^f = 0$ ($\mu^f = 1$) exists when the rate of return on the riskless activity is everywhere greater (less) than the expected marginal benefits from the risky activity.

It is also illustrative to consider the case where society maximizes the sum of expected net benefits from riskless and risky activities.[5] Society's problem is

(3) $$\underset{0 \le \mu \le 1}{\text{maximize}}\ (1 + r)(1 - \mu)x + p(\mu x)B - d(\mu x)h,$$

where the terms in (3) are returns from riskless and risky activities and expected harm from the risky activity.

At an interior solution, the first-order condition for problem (3) can be rearranged to yield

(4) $$(1 + r) = p'(\mu^s x)B - d'(\mu^s x)h,$$

where $\mu^s \equiv \mu^s(1 + r, x, B, h)$ is society's optimal investment choice, which is decreasing in $1 + r$, x, and h but increasing in B. Concavity of $p(\bullet)$ and convexity of $d(\bullet)$ ensure that second-order conditions are satisfied at an interior solution. Equation (4) has the usual interpretation that society equates the return from the riskless activity to the expected marginal net social benefits from the risky activity. A corner solution of $\mu^s = 0$ may occur as potential harm grows relative to benefits.

Problem (3) identifies the quandary facing society and policy makers. Society values the benefits from both riskless and risky activities but wants to limit its exposure to harm. Thus, the regulatory question involves designing institutions that provide the incentives for the firm to internalize expected damages $d(\mu x)h$ from the risky R&D activity.

Approaches for Controlling Public Risk

In the absence of a regulatory authority that can force a firm to allocate funds according to some social optimum, indirect methods must be used to provide the incentives for the firm to internalize potential externalities. Four approaches are considered: a fixed-cost regulatory standard, a marginal-cost regulatory standard, a property rule, and a strict-liability rule. While not explicitly considered in this paper, the model could also be generalized to analyze a negligence rule or the joint use of *ex ante* and *ex post* institutional approaches, such as a standard combined with a strict-liability rule.[6]

A Fixed-Cost Regulatory Standard

Consider first a fixed-cost regulatory standard, where q represents the cost of following the standard for conducting the risky activity. Given that the cost of the standard directly reduces a firm's assets, the expected-profit maximization problem of the firm becomes

(5) $$\underset{0 \le \mu \le 1}{\text{maximize}}\ (1 + r)(1 - \mu)(x - q) + p(\mu(x - q))B,$$

where the first term is income from the riskless activity, the second term is expected returns from the risky activity, and μ is the percentage of assets $(x - q)$ allocated to the risky activity. Although q is a fixed cost of conducting the risky activity, the level of q reduces firm wealth, which in turn affects the firm's choice of μ. The firm will allocate funds to the risky investment according to the optimum in equation (5) as long

[5] Because benefits and costs do not fall on identical parties, in which case the utility effects are not comparable, we do not imply that expected net benefits should be society's welfare criteria. However, the net-benefit objective remains a basis for comparing alternative regulatory approaches found in earlier works.

[6] Under a negligence rule, three basic conditions must be met for a firm to be held responsible for damages (Kahan). It must be shown that (*a*) the firm did not follow a stipulated level of due care, (*b*) damages were actually suffered, and (*c*) the firm's lack of due care actually caused the damages. In some situations, any contribution to damages created by the complaining party may also be considered. See Shavell (1987) and Kahan for more complete discussions.

as the resulting expected profit is greater than $(1 + r)x$. Thus, a standard could drive the firm out of the risky activity altogether, even though some level of the activity is socially desirable.

At an interior optimum, the first-order condition to (5) can be rearranged to yield

$$(6) \qquad (1 + r) = p'(\mu^n(x - q))B,$$

where $\mu^n \equiv \mu^f(1 + r, x - q, B)$ is the firm's optimal investment decision under the standard, which is decreasing in r and x and increasing in B and q.

When $0 < \mu^n < 1$, equations (2) and (6) imply that $1 + r = p'(\mu^n(x - q))B = p'(\mu^f x)B$, which occurs when $\mu^f x = \mu^n(x - q)$. Thus, the total level of investment in the risky activity under a standard remains equal to the level of investment for the unregulated firm. To maintain this equality of the marginal rates of return across the two activities, the firm under a regulatory standard must increase the percentage of its remaining assets to the risky activity.

Because the level of investment in the risky activity remains the same with or without the standard at an interior solution, society also faces the same amount of risk, i.e., $d(\mu^f x) = d(\mu^n(x - q))$. This result, while extreme in quantitative magnitude, is qualitatively similar to a result in Segerson and focuses on an important feature of a regulatory standard. The firm's ability to substitute around a standard to equalize rates of return across activities determines the effectiveness of a fixed-cost standard in reducing public risk. In Segerson, where standards are placed on only observable actions of the firm, a regulatory standard provides the incentive to substitute into unobservable actions. Thus, the degree of substitution in the probability function $d(\bullet)$ between directly productive activities and safety activities determines how effective the standard is in reducing risk.

A Marginal-Cost Regulatory Standard

The second approach is a constant marginal-cost standard, where a firm pays a fixed amount τ per unit of investment in the risky activity. Thus, if μx is invested in the risky activity, the firms pays $\tau\mu x$ in tax, and invests $(1 - \mu - \tau\mu)x$ in the riskless activity. Thus, the cost of following the standard increases with the investment in the risky activity.

For example, the USDA guidelines identify four levels of confinement, such as physical barriers to limit the release of an organism to the environment, that correspond to five levels of safety concerns identified in the document (OAB 21 May 1990). The NIH guidelines refer to four levels of containment, with level four being the most restrictive and costly (NIH). While both guidelines refer to the "safety" of the experiment, one way to improve safety is to reduce the size of the field test, either by "decreasing the number of organisms used in the experiment or decreasing the land area" (OAB March 1990, p. 32).

Under a marginal-cost standard, the firm's problem becomes

$$(7) \qquad \max_{\mu} \, (1 + r)(1 - \mu - \tau\mu)x + p(\mu x)B$$

$$\text{subject to } 1/(1 + \tau) \geq \mu \geq 0,$$

where the constraint ensures the firm does not violate its budget constraint.

Assuming an interior solution, the first-order condition can be rearranged to yield

$$(8) \qquad (1 + r) = p'(\mu^\tau x)B - \tau(1 + r),$$

where $\mu^\tau = \mu^\tau(1 + r, x, B, \tau)$ is decreasing in $1 + r$, x, and τ and increasing in B. The firm allocates funds to the risky investment according to equation (8) as long as expected profit at the optimum in (7) is greater than $(1 + r)x$.

Because of the wealth constraint of the firm, a marginal-cost standard implies an equal reduction in wealth (τ) as well as the opportunity cost of the lost investment from that wealth (τr). Thus, the total marginal cost of the standard is equal to $\tau(1 + r)$. It is directly observable from equation (8) that investment under a marginal-cost standard is always less than that for the unregulated firm or for the fixed-cost standard.[7]

A Property Rule (Environmental Bond)

With a property rule, the firm must post a bond, S, to conduct the risky activity, which is returned with interest if no accident occurs.[8] Be-

[7] The marginal-cost standard can also be interpreted as a marginal-tax rule. Note, however, from equations (4) and (8), that the optimal tax when the firm has a wealth constraint is $\tau^* = d'(\mu' x)h/(1 + r)$. Thus, at society's optimum and in the presence of constrained firm wealth, the optimal tax is less than expected marginal social damage.

[8] We use the term "property rule" following Bromley, and Calabresi and Melamed. In other words, under the property rule, a firm cannot interfere with society's entitlement to limit the risky activity unless the firm pays prior compensation (insurance in this case) in the form of the bond.

cause the firm retains ownership of the bond S when no damages are created, the property rule partially eliminates the incentives under a fixed-cost standard to increase the amount of available wealth allocated to the risky activity.

Under the property rule, the firm's problem becomes[9]

$$(9)\quad \max_{0\le\mu\le 1} (1+r)(1-\mu)(x-S) + p(\mu(x-S))B + [1-d(\mu(x-S))](1+r)S,$$

where the first two terms in (9) are the returns from the riskless investment and the expected returns from the risky activity, the last term is the amount the firm expects to have returned after conducting the risky activity, and μ is interpreted as the percentage of assets $x - S$ allocated to the risky activity. From the firm's point of view, the bond is equivalent to allocating a predetermined amount in a third asset with an uncertain rate of return $(1 + r)(1 - d(\mu(x - S))) < (1 + r)$.

Assuming an interior solution, the first-order condition for the firm under a property rule can be rearranged to yield

$$(10)\quad (1+r) = p'(\mu^p(x-S))B - S(1+r)d'(\mu^p(x-S)),$$

where $\mu^p \equiv \mu^p(1 + r, x - S, B, (1 + r)S)$ is decreasing in $1 + r$ and x, increasing in B, and indeterminate in S. The firm will conduct the risky activity according to equation (10) as long as profits at the optimum in equation (9) are greater than $(1 + r)x$.

The allocation of funds under a property rule can be readily compared to firm choices under a regulatory standard and society's problem. First, assuming interior solutions and $d'(\bullet) > 0$, equations (6) and (10) imply that $p'(\mu^p(x - S)) - p'(\mu^n(x - q)) = (S/B)(1 + r)d'(\mu^p(x - S)) > 0$. As a result, because of $p'(\bullet) > 0$ and the concavity of $p(\bullet)$, $\mu^p(x - S) < \mu^n(x - q)$. Thus, with interior solutions, total investment in the risky activity under a property rule with bond S is less than total investment under a standard with costs q, and expected damages are less under the property rule than the regulatory standard.

Second, assuming interior solutions and a bond of $S = h/(1 + r)$, equations (4) and (10) imply that $p'(\mu^s x)B - d'(\mu^s x)h = 1 + r = p'(\mu^p(x - S))B - d'(\mu^p(x - S))h$ when $\mu^s x = \mu^p(x - S)$. Thus, when the bond is set such that $S = h/(1 + r)$, total investment in the risky activity under the property rule is equal to the social optimum. As a result, investment in the risky activity and expected damages are larger than what are socially desirable under a property rule for levels of S below the value $h/(1 + r)$, and vice versa.

Strict Liability

Under a strict-liability rule, the firm pays compensation for damages if damages occur and if the firm is shown to have caused the damage (Harl; Johnson and Ulen; Shavell, 1984a). For example, even though damages occur, scientific knowledge may not be available to determine that the firm's actions caused the damages (Johnson and Ulen), or damaged parties may not be able to prove successfully in court that the firm caused the damages (Cooter). Previous literature on strict liability recognizes that bankruptcy laws or finite firm assets may reduce the incentives for precaution (Cooter; Johnson and Ulen; Rizzo; Shavell 1987, 1984a,b, 1980). In effect, firm decisions do not influence the maximum amount of compensation that the firm can pay. Thus, two cases are considered: one where the firm can compensate fully for damages and one where the firm cannot compensate fully.

In the model analyzed here, the firm's final wealth position is random when decisions are made. As a result, the firm's ability to pay compensation is also random. If h is the level of damage caused by the risky activity when an accident occurs, the potential compensation the firm can pay under strict liability is $\min[h, (1 + r)(1 - \mu)x]$ if the risky activity is not successful and $\min[h, (1 + r)(1 - \mu)x + B]$ if successful.

In effect, three situations may be relevant for the firm and society after the risky activity is conducted. As shown in figure 1, the relevance of the three cases depends on firm size (x), the potential return from the risky activity (B), the riskless rate of return $(1 + r)$, and the potential harm (h). In case 1, where $0 \le h \le (1 + r)(1 - \mu)x$, the firm is always able to compensate fully for harm after conducting the risky activity. In case 2, where $(1 + r)(1 - \mu)x \le h \le (1 + r)(1 - \mu)x + B$, the firm is only able to compensate fully for harm if it is successful in

[9] Another type of property rule could specify a bond S that must be posted before conducting the risky activity, but the firm is reimbursed $S(1 + r) - h$ if an accident occurs when $S(1 + r) > h$, and the firm is liable for the additional amount $h - S(1 + r)$ if an accident occurs when $h > S(1 + r)$. For brevity, only one type of property rule is examined here. A variable bond rule of $S(\mu x)$ could also be considered where $S'(\mu x) > 0$.

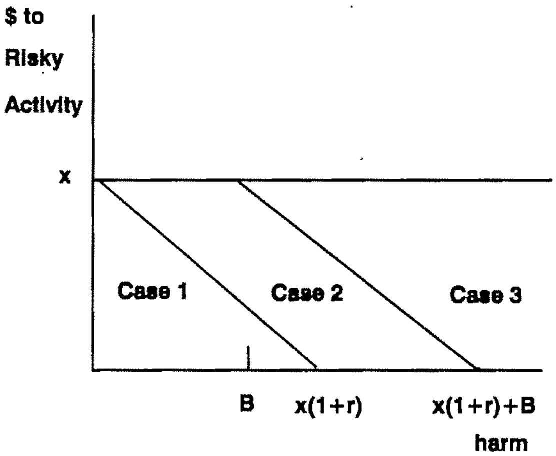


Figure 1. Three cases under liability

the risky activity.[10] And in case 3, where $(1 + r)(1 - \mu)x + B \leq h$, the firm is not able to compensate fully for harm even if it is successful in the risky activity.[11]

In general, to determine the optimal allocation of wealth under a strict-liability rule, the firm must solve

$$(11)\quad \max_{0 \leq \mu \leq 1}\ (1 + r)(1 - \mu)x + p(\mu x)B - d(\mu x)t\{p(\mu x)\min[h,\ (1 + r)(1 - \mu)x + B] + (1 - p(\mu x))\min[h,\ (1 + r)(1 - \mu]\},$$

where the first two terms are expected income from the riskless and risky activity, t is the probability that the firm is shown to be responsible for damages, and the last term is expected liability from conducting the risky activity. In general, the firm's decision problem (11) can be analyzed as follows. Given the parameters of the problem, the firm first chooses for each possible case the optimal μ_i^L, where $i = 1, 2, 3$, for the three cases. From this set of μ_i^L's, the firm then chooses the μ_i^L that maximizes overall expected profits.

The firm's optimal choice in case 1, where full compensation is possible, is essentially the standard result for a strict liability rule (Shavell 1984a) when bankruptcy or limited liability is not an issue. The firm's first-order condition in case 1 is identical to society's decision rule (4) except, because the firm is not sued with certainty, expected liability is now only th. Thus, resources allocated to the risky activity under a liability rule for case 1 are greater than for society's expected net-benefit criteria.[12] However, investment in the risky activity in case 1 is less than that for the unregulated firm and for the firm under the regulatory standard. A strict liability rule in case 1 is also equivalent to a property rule where the bond is set such that $S = th/(1 + r)$.

The firm's first-order condition for case 2, where full compensation for damages is only possible if the firm is successful, and the first-order condition for case 3, where full compensation is never possible, show how the presence of random firm wealth complicates well-known liability results. In case 2, expected liability is equal to $t\{p(\mu_2 x)h + (1 - p(\mu_2 x))(1 + r)(1 - \mu_2)x\}$, while in case 3 expected liability is equal to $t\{p(\mu_3 x)B + (1 + r)(1 - \mu_3)x\}$. Because expected liability falls from case 1 to case 2 to case 3, one would expect that the allocation of wealth to the risky activity should increase in case 2 and case 3 relative to case 1. In fact, this result is directly observable from figure 1. For example, case 1 and case 2 are possible when $h \leq B$. For any level of $h \leq B$, the allocation of assets to the risky activity for case 1 must be less than that for case 2. All three cases are possible when the level of harm is in the range $B \leq h \leq x(1 + r)$, which implies that the allocation of assets to the risky activity is lowest for case 1 and greatest for case 3. When the level of harm is in the range $x(1 + r) \leq h \leq x(1 + r) + B$, case 2 and case 3 are possible, and the allocation of assets to the risky activity for case 2 must be less than that for case 3. Only case 3 is possible when $x(1 + r) + B \leq h$.

For the multiactivity firm under uncertainty, random firm wealth and the option of bankruptcy can dilute the incentives for safety beyond what is already recognized in the literature. The incentives for safety are also reduced as firm size decreases relative to potential returns. Thus, the results in this section are qualitatively similar to earlier studies (e.g., Shavell 1987), but this dilution grows as potential benefits and/or harm increase relative to firm wealth. A firm that is wealthy relative to h and B will probably choose μ_1^L or μ_2^L, generating a case 1 or case 2 outcome. However, all three cases may

[10] The line separating case from case 2 in figure 1 is defined by $f(h) = x - h/(1 + r)$ for $0 \leq h \leq x(1 + r)$.

[11] The line separating case 2 from case 3 in figure 1 is $g(h) = x - (h - B)/(1 + r)$ for $B \leq h \leq x(1 + r) + B$.

[12] As Shavell (1984a) notes, a liability rule of the form h/t creates the incentive to allocate resources according to the social net-benefit criterion.

be relevant for medium size firms relative to h and B. Case 2 or case 3 may be most relevant for the smallest firms relative to h and B. Future research is needed to consider the relative importance of three cases for different situations—types and location of firms in various industries, and how strict liability might provide the incentives to conduct certain risky activities in a small firm setting.[13]

Conclusions

This analysis shows how four policy approaches create different incentives to conduct risky research activities. All of the approaches are least effective at controlling public risks and providing the incentives to conduct the research activity when the research firm is small in size (defined by wealth) relative to the benefits that may follow from the research. For example, under the fixed-cost regulatory standard, a marginal-cost standard, or a property rule, it is very possible that a firm would find a corner solution optimal and allocate no wealth to the risky activity. As a result, public regulation could drive relatively small firms out of the industry, the very firms that are playing a central role in bringing new agricultural biotechnologies to the market.

While this paper begins to address the effects of institutional choice on resource allocation by the firm, many issues remain. Issues for further investigation include risk-averse research firms, dynamics in the research process, learning, and the temporal resolution of uncertainty. Throughout the paper, it is also assumed that a regulatory agency can enforce the different types of policies. However, the costs of implementing and enforcing environmental policies are central to regulation under uncertainty. In the presence of asymmetric and imperfect information, firms may choose which regulatory regime is preferred through compliance with regulatory standards or a property rule or through noncompliance and the liability regime. Thus, further research is needed to analyze how firm decisions depend on the specific design, implementation, and enforcement of the various regulatory mechanisms. Other types of policies warrant further investigation. For example, joint and several liability is another litigation strategy, which has been applied to toxic waste clean up under the Comprehensive Environmental Response, Compensation, and Liability Act (Tietenberg). Under joint and several liability, one firm can be held responsible for all the damages created by a group of firms. This type of liability could have implications for joint biotechnology research conducted by private firms and public groups such as universities or government agencies.

[Received June 1990; final revision received January 1991.]

References

Bromley, D. W., "Property Rules, Liability Rules, and Environmental Economics." *J. Econ. Issues* 12(1978):43–60.

Calabresi, G., and A. D. Melamed. "Property Rules, Liability Rules, and Inalienability: One View of the Cathedral." *Harvard Law Rev.* 85(1972):1089–1128.

Coase, R. "The Problem of Social Cost." *J. Law Econ.* 3(1960):1–44.

Cooter, R. "Liability Rules and Risk Sharing in Environmental and Resource Policy: Discussion." *Amer. J. Agr. Econ.* 68(1986):1276–78.

Crawford, M. "Biotech Companies Lobby for Federal Regulation." *Science* 248(1990):546–47.

Demsetz, H. "The Exchange and Enforcement of Property Rights." *J. Law and Econ.* 7(1964):11–26.

Fishelson, G. "Emission Control Policies Under Uncertainty." *J. Environ. Econ. and Manage.* 3(1976):189–97.

General Accounting Office (GAO). "Biotechnology: Managing the Risks of Field Testing Genetically Engineered Organisms." Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives, June 1988.

Harl, N. E. *Agricultural Law*. New York: Mathew Bender & Co., 1990.

Johnson, G. V., and T. S. Ulen. "Designing Public Policy Toward Hazardous Wastes: The Role of Administrative Regulations and Legal Liability Rules." *Amer. J. Agr. Econ.* 68(1986):1266–71.

Kahan, M. "Causation and Incentives to Take Care Under the Negligence Rule." *J. Legal Stud.* 18(1989):427–47.

National Institute of Health (NIH). "Guidelines for Research Involving Recombinant DNA Molecules." 51 *Federal Register* 16958–23393, 7 May 1986.

National Research Council (NRC). *Field Testing Genetically Modified Organisms: Framework for Decisions*. Washington DC: National Academy Press, 1989.

Office of Agricultural Biotechnology (OAB). *Agricultural Biotechnology: Introduction to Field Testing*, ed. H.

[13] As Ringleb and Wiggins find in the context of corporations in hazardous sectors in the United States, legal liability may also create incentives to divest certain hazardous activities of a larger-scale firm into smaller autonomous units to limit exposure to large liability payments.

Graham and D. R. Mackenzie. Washington DC, March 1990.
——. "Guidelines for Research with Genetically Modified Organisms Outside Contained Facilities," draft. Washington DC, 21 May 1990.
Office of Science and Technology Policy (OSTP), Executive Office of the President. "Coordinated Framework for Regulation of Biotechnology, Announcement of Policy and Notice for Public Comment." 51 *Federal Register* 23302–23393, 26 June 1986.
Ringleb, A. H., and S. N. Wiggins. "Liability and Large-Scale, Long-Term Hazards." *J. Polit. Econ.* 98(1990): 574–95.
Rizzo, M. J. "Law Amid Flux: The Economics of Negligence and Strict Liability in Tort." *J. Legal Stud.* 9(1980):291–318.
Segerson, K. "Risk Sharing in the Design of Environmental Policy." *Amer. J. Agr. Econ.* 68(1986):1261–65.
Shavell, S. "A Model of the Optimal Use of Liability and Safety Regulation." *Rand J. Econ.* 15(1984a):271–80.
——. *Economic Analysis of Accident Law*. Cambridge MA: Harvard University Press, 1987.
——. "Liability for Harm Versus Regulation of Safety." *J. Legal Stud.* 13(1984b):357–74.
——. "Strict Liability Versus Negligence." *J. Legal Stud.* 9(1980):1–25.
Tietenberg, T. H. "Indivisible Toxic Torts: The Economics of Joint and Several Liability." *Land Econ.* 65(1989):305–19.
Watson, W. D., and R. G. Ridker. "Losses from Effluent Taxes and Quotas Under Uncertainty. *J. Environ. Econ. and Manage.* 11(1984):310–26.
Weitzman, M. L. "Prices vs. Quantities." *Rev. Econ. Stud.* 41(1974):477–91.
White, M. J., and D. Wittman. "A Comparison of Taxes, Regulation, and Liability Rules Under Imperfect Information." *J. Legal Stud.* 12(1983):413–25.
Yohe, G. W. "Substitution and the Control of Pollution: A Comparison of Effluent Charges and Quantity Standards Under Uncertainty. *J. Environ. Econ. and Manage.* 3(1976):313–24.
——. "Towards a General Comparison of Price Controls and Quantity Controls Under Uncertainty." *Rev. Econ. Stud.* 45(1978):229–38.

Allocable Fixed Inputs as a Cause of Joint Production: A Cost Function Approach

Howard D. Leathers

The multiproduct cost concepts of Baumol, Panzar, and Willig are used to explore the contention of Shumway, Pope, and Nash that allocable fixed inputs cause joint production. Allocable fixed inputs may create an interdependence in the short-run cost function when none exists in the long run; however, this will not necessarily lead to joint production. For joint production to occur in the short run, either the short-run cost function must exhibit economies of scope, or stand-alone production of one of the commodities must exhibit diseconomies of size. The issue of whether allocable fixed inputs cause joint production is an empirical question.

Key words: allocable fixed inputs, joint production, multiproduct cost function.

In a widely discussed article, Shumway, Pope, and Nash (SPN 1984) argued that many instances of multi-output production in agriculture are caused by allocable fixed inputs. A recent exchange between Lynne and SPN 1988 focused attention on how "jointness" should be defined, and whether it was important to make a distinction between joint production that was caused by technical interdependence and joint production that was caused by the existence of allocable fixed inputs. This paper introduces into this debate the multiproduct cost concepts developed by Baumol, Panzar, and Willig (BPW).

Framing the issues in terms of BPW's joint cost function concepts gains several insights. First, the cost function formulation emphasizes that allocable inputs can cause jointness only in the short run (the period over which total amounts of some allocable inputs are fixed). Second, the cost function formulation confirms SPN's argument that allocable fixed inputs create an interdependence in the short-run cost function when there is no technical interdependence in the long run. In the vernacular of BPW, the existence of allocable fixed inputs can create economies or diseconomies of scope in the short-run cost function.

This paper identifies necessary conditions for joint production in the short run. In order for joint production to occur in the short run, either the short-run cost function must exhibit economies of scope or stand-alone production of one of the goods must exhibit diseconomies of size. Therefore, showing that a cost interdependence (caused by allocable fixed inputs) exists does not prove that joint production is a profit-maximizing choice in the short run. Whether and to what extent allocable fixed inputs cause joint production is an empirical question that can be answered by estimating a short-run multiproduct cost function.

The Multiproduct Cost Function Approach to Jointness

In the framework of BPW's contestable markets, in which firms can enter and exit costlessly (i.e., no fixed inputs), the only circumstance in which joint production will occur is when joint production is cheaper than nonjoint, single-output ("stand-alone") production. To understand the BPW approach and to lay a foundation for the rest of this paper, a few of BPW's definitions and results are presented.

A multiproduct cost function $C(y) \equiv C(y_1, \ldots, y_l)$ shows the minimum cost of producing, in a single firm, quantity y_1 of commodity 1,

Howard D. Leathers is an assistant professor, Department of Agricultural and Resource Economics, University of Maryland.

This is MAES Scientific Article No. A 6121.

This research was funded by Maryland Agricultural Experiment Station Project No. A-38.

quantity y_2 of commodity 2, etc.[1] The choice of the commodity set S is arbitrary: the commodities can include things (sheep, home computers) which are not produced together in reality. As a conceptual tool, the multiproduct cost function is therefore very general and does not require pre-identification of products which are jointly produced. The commodity set, S, can be partitioned into mutually exclusive subsets $P = \{T_1, \ldots, T_K\}$ and we can identify the cost function of producing the partitioned subset T_K by setting $y_j = 0$ for any commodity j not included in T_K. One of these partitions is the "complete partition" in which every subset contains exactly one of the J commodities; thus, the multiproduct cost function contains as a special case the single-product cost function $C(0, 0, \ldots, y_j, 0, \ldots)$ for the firm producing only commodity j. For notational simplicity, the cost of producing partition T_k is written $C(y_{T_k})$ and the single-product cost function is written $C(y_j)$.

In order to describe the circumstances under which joint production will occur, BPW introduce the concept of "economies of scope."

DEFINITION. *For any output vector,* y, *and any partition* P, *there are economies of scope at* y *with respect to* P, *if*

$$\sum_{k=1}^{K} C(y_{T_k}) > C(y).$$

If the inequality is reversed, there are diseconomies of scope. If the inequality is weak, then there are weak economies of scope.

In the BPW framework, with costless entry and exit, (weak) economies of scope are necessary for the existence of multiproduct firms (BPW, pp. 248–49). If there are no economies of scope, then it is more costly to produce the commodities in a single firm than it is to split up the commodities into the partition P and have K firms producing the commodities. Because entry and exit are free, firms producing the partition P can drive the single firm producing S out of business.

This approach focuses on technological causes of joint production. Economies of scope exist because something inherent in the production technology makes it cheaper to produce the products jointly. The concept of economies of scope as a cause of joint production is closely related to classical economic thought on the subject. For example, Carlson asks: "[How] does . . . technical interdependence between products influence the relationship between costs and output? . . . [T]he total cost of the joint output of the two products is less than the sum of [what] the total costs would be if the two products were produced separately. There would be no inducement for joint production were this not true" (p. 81).

BPW identify two types of technical interactions that can cause economies of scope. The first type of interaction occurs when increased production of one good causes a decline in marginal cost of other goods:

$$\partial^2 C/\partial y_i \partial y_j < 0.$$

This condition is called "cost complementarity" by BPW and defines "technically complementary products" for Carlson. The second type of interaction occurs when two products share some fixed costs.[2] To define this condition formally, BPW divide the cost function into fixed costs (F) and variable costs (V) as $C(y) = F(T) + V(y)$. Fixed costs depend on which products are produced: $T = \{i \in S | y_i > 0\}$. Two disjoint product sets T_i and T_j share fixed costs when the F functions are subadditive:

$$F(T_i) + F(T_j) > F(T_i \cup T_j).$$

Jointness Caused by Allocable Fixed Inputs

At first glance, the assertion that economies of scope or technical interdependence is the only cause of joint production seems to be at odds with the SPN demonstration that there can be joint production even when production is nonjoint in inputs. The assumption of nonjointness in inputs is a very powerful assumption. It means that a joint production function exists, and that the production function for each output j can be written as $y_j = f_j(x_{ij})$, where $x_i = \Sigma_j x_{ij}$.[3] In other words, the inputs x_i can be split up among, or

[1] For notational simplicity, input prices w and r are suppressed in writing cost functions.

[2] The BPW analysis assumes no fixed inputs but permits fixed costs. Fixed cost is defined as the limit of the cost function as the output vector approaches zero from above. Fixed costs are not the same as "sunk costs," the cost incurred when output is equal to zero. In a contestable market, firms can acquire or divest the assets, which account for fixed costs in a perfect market; thus there are no "sunk costs." There may, however, be fixed costs.

[3] As Shephard pointed out, existence of a multiproduct production function is not assured by the usual assumptions of production. The intuitive reasons for this are explained succinctly by Knudsen. Conditions to ensure existence of a production function in the multioutput case are explored by Al-Ayat and Färe.

"allocated" to, the various outputs; there is no input which simultaneously contributes to production of two commodities.

In order to explore the implications of nonjointness in inputs and allocable fixed inputs for the structure of cost, it is useful to present the following terminology. As above, y is the vector of output, x is the vector of variable inputs, z is the vector of inputs that are fixed in the short run, and z_j is the vector of fixed inputs allocated to production of output j.[4] In addition, r is the vector of prices for x, w is the vector of prices for z, and Θ is the feasible production set.

The total long-run cost function is

$$(1)\quad C(y) = \min_{x,z} r'x + w'z \text{ s.t. } (x, z, y) \in \Theta.$$

The short-run cost function is

$$(2)\quad c^s(y|\bar{z}) = \min_{x,z_j} r'x \text{ s.t. } (x, z_1, z_2, \ldots, z_J, y) \in \Theta \text{ and } \Sigma z_j = \bar{z}.$$

The short-run cost function holds the total amount of fixed inputs constant. The short-short-run cost function is

$$(3)\quad c^{ss}(y|z_1, z_2, \ldots, z_J) = \min_{x} r'x \text{ s.t. } (x, z_1, z_2, \ldots, z_J, y) \in \Theta.$$

The short-short-run cost function holds constant the total amount of fixed inputs and the allocations of the fixed inputs z_j for each output j.

The cost functions are related to each other as follows:

$$(4)\quad c^s(y|\bar{z}) = c^{ss}(y|z_1^*, z_2^*, \ldots, z_J^*),$$

where z_j^* are the optimal allocations of z from the c^s minimization problem.

$$(5)\quad C(y) = w'z^* + c^s(y|\bar{z}^*),$$

where $\bar{z}^*$ is the optimal choice of fixed input in the C minimization problem. This terminology is used in making the following points.

PROPOSITION 1. *Nonjointness in inputs implies that (strong) economies of scope do not exist in the long-run cost function at any level of output, with respect to any partition of the commodity set.*

Proof: The cost function dual to a production function which is nonjoint in inputs is

$$C(y) = \min_{x_i} \sum_i r_i x_i \text{ s.t. } y = f(x)$$

$$= \min_{x_{ij}} \sum_i r_i \cdot \left[\sum_j x_{ij}\right] \text{ s.t. } y_j = f_j(x_{ij})$$

for each element y_j of the vector y;

$$= \sum_j \min_{x_{ij}} \sum_i r_i x_{ij} \text{ s.t. } y_j = f_j(x_{ij})$$

$$= \sum_j C(y_j),$$

where $C(y_j)$ is the cost of producing y_j in a specialized firm. □

Therefore, under the assumption of nonjointness in inputs, there are no economies or diseconomies of scope in the long run. Any configuration of outputs—the J commodities produced by a single firm, or by J single-output firms, or by $K \leq J$ firms producing any partition of the output set—will have the same total cost of output. There is, under this assumption, no "technological imperative" for joint production; that is, there are no cost savings to be gained by joint production in the long run.[5]

But if the assumption of nonjointness in inputs precludes technological causes of jointness (the causes of economies of scope), what is causing the firms in these models to produce more

[4] While this notation follows that of SPN, it contains some potential for confusion. The z_j's are not elements, but subvectors of the vector z. If there are K types of fixed inputs, then there are K elements (z_{jk}) of each subvector z_j and there are $K \cdot J$ elements of the vector z. In the long run, each of these elements is chosen. In the short run, the K elements of the vector $\bar{z}$ (total amounts of the fixed inputs) cannot be changed, but the $K \cdot J$ z_j's can be chosen (subject to the constraint that they must add up to $\bar{z}$). When the fixed input is not allocable (when the production function is not nonjoint in fixed and variable inputs), the allocations z_j may be somewhat arbitrary. For example, if two of the outputs are mutton and wool, and one of the fixed inputs is animal pens, it does not make any practical difference whether one pen is allocated to mutton and zero to wool, or zero to mutton and one to wool, or one-half pen to mutton and one-half pen to wool. The only requirement is that the allocation and output level is in the feasible set.

[5] Just, Zilberman, and Hochman argue that nonjointness in inputs is a reasonable assumption in agriculture (p. 772). Knudsen, on the other hand, recognizes that the assumption creates "a convenient state of affairs" but argues that it is of "very limited value" because it "will not as a rule be the case" (pp. 114–15). Knudsen's objection seems to be that, having observed multiproduct firms as a fact of life, it is disingenuous to assume away any technological imperative for such multiproduct firms. SPN (1984) reject the nonjointness assumption in their text ("jointness is descriptive of agricultural supplies," p. 74) but utilize a production function that is nonjoint in inputs in their model [equations (10)–(12), p. 74]. This is ideal for SPN purposes because, as proposition 1 shows, it creates a model in which there is no technological interdependence and in which jointness can be caused only by allocable fixed inputs. However, it sidesteps the issue of whether or not the assumption of nonjointness inputs is realistic.

than one product? The answer offered by SPN is that there is a fixed input which is not fully utilized in producing a single product at optimal scale: "[T]echnological interdependence . . . generally result[s] in joint technology. . . . Another cause is the presence of a constraint on an allocable input. . . . [T]his case is particularly representative of agriculture" (p. 74).

An example of joint production caused by allocable fixed inputs is presented by SPN in which the production functions for goods 1 and 2 are

$$y_1 = f_1(x_1, z_1),$$
$$y_2 = f_2(x_2, z_2), \text{ and}$$
$$z_1 + z_2 = \bar{z}.$$

These production functions are nonjoint in inputs; nevertheless, the decision of how much of good 1 to produce is influenced by the price of good 2, and vice versa. Below, production functions such as this that are nonjoint in inputs (NJI) and which have allocable fixed inputs (AFI) are referred to as NJI-AFI production functions.

This example serves as a basis for examining the relationship between economies of scope in the short-run cost function and allocable fixed inputs. First, notice that the short-short run cost function dual to an NJI-AFI production function exhibits neither economies nor diseconomies of scope:

(6)
$$\begin{aligned} c^{ss}(y_1, y_2|z_1, z_2) &= \min_x r\cdot(x_1 + x_2) \text{ s.t. } y_1 \\ &= f_1(x_1|z_1)\; y_2 = f_2(x_2|z_2) \\ &= \min_{x_1} rx_1 \text{ s.t. } y_1 = f_1(x_1|z_1) \\ &\quad + \min_{x_2} rx_2 \text{ s.t. } y_2 = f_2(x_2|z_2) \\ &= c^{ss}(y_1|z_1) + c^{ss}(y_2|z_2). \end{aligned}$$

The short-short-run cost of producing y jointly in a firm with fixed input z allocated (z_1, z_2) would be exactly the same as the short-short run cost of producing y_1 in a firm with fixed input z_1 and producing y_2 in a firm with fixed input z_2.

Therefore the short-run cost function associated with the NJI-AFI production function is

(7)
$$\begin{aligned} c^s(y_1, y_2|\bar{z}) &= c^{ss}(y_1, y_2|z_1^*(y_1, y_2, \bar{z}), z_2^*(y_1, y_2, \bar{z})) \\ &= c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z})) \\ &\quad + c^{ss}(y_2|z_2^*(y_1, y_2, \bar{z})). \end{aligned}$$

We use this result to prove the following propositions.

PROPOSITION 2. *The NJI assumption precludes shared fixed costs in the short-run cost function.*

Proof. Fixed costs in the short run are defined as

$$\lim_{y\Rightarrow 0} c^s(y|\bar{z}) = \lim_{y\Rightarrow 0} c^{ss}(y_1|z_1^*) + \lim_{y\Rightarrow 0} c^{ss}(y_2|z_2^*).$$

This shows that in the short run, fixed costs are additive across commodities. □

The possibility now exists for cost complementarities.

PROPOSITION 3. *The AFI assumption creates the possibility that there will be cost complementarities or anticomplementarities in the short-run cost function.*

Proof. First, notice that the problem of allocating $\bar{z}$ to z_1 and z_2 is

$$\min_{z_1, z_2} c^{ss}(y_1|z_1) + c^{ss}(y_2|z_2) \text{ s.t. } z_1 + z_2 = \bar{z}.$$

The first-order conditions imply that, at the optimal allocation of z:

(8) $\partial c^{ss}(y_1|z_1^*)/\partial z_1 = \partial c^{ss}(y_2|z_2^*)/\partial z_2$, and

(9) $z_2^* = \bar{z} - z_1^*.$

Therefore, differentiating (7), and noting that optimal allocations z^* are functions of y_1, y_2, and $\bar{z}$:

(10)
$$\begin{aligned} \frac{\partial c^s}{\partial y_1} &= \frac{\partial c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial y_1} \\ &\quad + \frac{\partial c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial z_1}\frac{\partial z_1^*}{\partial y_1} \\ &\quad + \frac{\partial c^{ss}(y_2|z_2^*(y_1, y_2, \bar{z}))}{\partial z_2}\frac{\partial z_2^*}{\partial y_1} \\ &= \frac{\partial c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial y_1} \\ &\quad + \frac{\partial c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial z_1}\left[\frac{\partial z_1^*}{\partial y_1} + \frac{\partial z_2^*}{\partial y_1}\right] \end{aligned}$$

from equation (8)

$$= \frac{\partial c^{ss}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial y_1}$$

since from equation (9),

$$\frac{\partial z_1^*}{\partial y_1} = -\frac{\partial z_2^*}{\partial y_1}$$

$$\frac{\partial^2 c^s(y_1, y_2|\bar{z})}{\partial y_1 \partial y_2} = \frac{\partial^2 c^{su}(y_1|z_1^*(y_1, y_2, \bar{z}))}{\partial y_1 \partial z_1} \cdot \frac{\partial z_1^*}{\partial y_2}.$$

If this is negative, then cost complementarities exist in the short run; if it is positive, then cost anticomplementarities exist. □

The sign of (10) cannot be determined by theory alone. Yet, this sign is central to the argument that allocable fixed inputs cause jointness. The existence of cost complementarities at y [the sign of (10) is negative] and the additivity of fixed costs is a sufficient condition for economies of scope at y (BPW or Gorman). Therefore, the short-run cost function could exhibit economies of scope in the case of an NJI-AFI production function. However, note that the "normal" case of (10) would be one where $\partial^2 c^{su}(y_1|z_1^*)/\partial y_1 \partial z_1 < 0$ (increasing the amount of the fixed input reduces the marginal variable cost of production), and where $\partial z_1^*/\partial y_2 < 0$ (when the amount of good 2 produced increases, the amount of fixed input allocated to production of good 1 declines). In this "normal" case, $\partial^2 c^s/\partial y_1 \partial y_2$ is greater than zero; an increase in the production of good 2 increases the marginal cost of good 1; in the vernacular of BPW, there are cost anticomplementarities (and diseconomies of scope in the short-run cost function).

Thus, in one respect, proposition 3 confirms the SPN claim that allocable fixed inputs can cause joint production. However, in another respect, proposition 3 raises doubts about whether this theoretical possibility is likely to occur in reality. This issue is explored in the next section.

A Cost Function Condition for Joint Production in the Short Run

Under what conditions will the producer choose to produce jointly in the short run? When joint production is more profitable than stand-alone (specialized) production. The implications of this simple statement are explored next. A necessary condition for joint production is derived in terms of the short run cost function. The following notation is used: $y^J = (y_1^J, y_2^J)$ is the output level that maximizes (short-run) profits in a firm with fixed input $\bar{z}$ producing both commodities; y_1^N and y_2^N are the output levels that maximize profits for a specialist (nonjoint) firm with fixed input $\bar{z}$ producing only one of the two goods. The analysis and proofs are easily extended to the case of more than two goods.

DEFINITION. *A firm will jointly produce both commodities in the short run if and only if joint production is at least as profitable as nonjoint production of either product:*

$$\text{(11}a\text{)} \quad p_1 y_1^J + p_2 y_2^J - c^s(y_1^J, y_2^J|\bar{z}) \geq p_1 y_1^N - c^s(y_1^N|\bar{z})$$

$$\text{(11}b\text{)} \quad p_1 y_1^J + p_2 y_2^J - c^s(y_1^J, y_2^J|\bar{z}) \geq p_2 y_2^N - c^s(y_2^N|\bar{z}).$$

PROPOSITION 4. *If joint production occurs in the short run, then*

$$\text{(12)} \quad c^s(y_1^J, y_2^J|\bar{z}) \leq k \cdot c^s(y_1^J/k|\bar{z}) + (1-k) \cdot c^s(y_2^J/(1-k)|\bar{z}) \quad 0 < k < 1.$$

Proof. Because the y^N's are the profit-maximizing choices for the nonjoint firms, profits at that output level must be at least as high as profits at any other output level:

$$\text{(13}a\text{)} \quad p_1 y_1^N - c^s(y_1^N|\bar{z}) \geq p_1 \cdot [y_1^J/k] - c^s(y_1^J/k|\bar{z}) \text{ for all } k$$

$$\text{(13}b\text{)} \quad p_2 y_2^N - c^s(y_2^N|\bar{z}) \geq p_2 \cdot [y_2^J/(1-k)] - c^s(y_2^J/(1-k)|\bar{z}) \text{ for all } k.$$

Because (13) must hold for all k it must hold for $k \in (0, 1)$. Restricting k to this range, combining (11) and (13), and multiplying by k and $(1-k)$ joint production implies

$$\text{(14}a\text{)} \quad k \cdot [p_1 y_1^J + p_2 y_2^J - c^s(y_1^J, y_2^J|\bar{z})] \geq p_1 y_1^J - k \cdot c^s(y_1^J/k|\bar{z})$$

$$\text{(14}b\text{)} \quad (1-k) \cdot [p_1 y_1^J + p_2 y_2^J - c^s(y_1^J, y_2^J|\bar{z})] \geq p_2 y_2^J - (1-k) \cdot c^s(y_2^J/(1-k)|\bar{z}).$$

Summing (14a) and (14b) yields condition (12). □

Proposition 4 gives a necessary, but not sufficient, condition for joint production.[6]

[6] To see that (12) is not a sufficient condition, note the following. The sufficiency proof would demonstrate that (12) implies (11), or conversely, that "not (11)" implies "not (12)." "Not (11)" would reverse the inequality in (11), but the inequality in (13) would not be reversed; therefore, no statement analogous to (14) is possible.

The institution behind this condition is straightforward. For heuristic purposes, let $k = 1/2$. Then condition (12) states that

$$(15)\quad c^s(y_1^J, y_1^J|\bar{z}) \leq (1/2) \cdot [c^s(2y_1^J|\bar{z}) + c^s(2y_2^J|\bar{z})].$$

If (15) did not hold, then two firms could produce output vector $2y^J$ more cheaply by nonjoint production than by joint production of y^J in each firm. Therefore, joint production could not be profit maximizing for the two firms.[7]

Proposition 4 can be reinterpreted in more familiar economic terms.

PROPOSITION 5. *If joint production occurs at* y^J, *then one of the following conditions must hold for the short run-cost function:*

(*a*) *There are economies of scope at* y^J *with respect to the "complete partition" in the short-run cost function.*

(*b*) *There are diseconomies of size in nonjoint production at* y^J *in the short-run cost function.*

Proof. Suppose neither condition holds. No diseconomies of size in nonjoint production means that increasing output of the firm by a factor of $(1/k) > 1$ will increase costs by less than or equal to $(1/k)$. Therefore,

$$(16)\quad kc^s(y_1^J/k) \leq c^s(y_1^J) \text{ and } (1-k)c^s(y_2^J/(1-k)) \leq c^s(y_2^J),$$

and condition 12 implies

$$(17)\quad c^s(y_1^J, y_2^J|\bar{z}) \leq kc^s(y_1^J/k) + (1-k)c^s(y_2^J/(1-k)) \leq c^s(y_1^J|\bar{z}) + c^s(y_2^J|\bar{z}).$$

The first inequality in (17) is a restatement of (12), and the second inequality is from (16). This contradicts diseconomies of scope at y^J, which implies

$$c^s(y_1^J, y_2^J|\bar{z}) > c^s(y_1^J|\bar{z}) + c^s(y_2^J|\bar{z}). \quad \square$$

The intuition behind the proposition is the following. One of two conditions must be met in order to have joint production of a vector y. The first condition is that is is cheaper in the short run to produce y jointly than to produce the y_i's in specialized firms; in a sense, the farmer can reduce the cost of producing y_1 by adding production of a second good. As shown in the previous section, the existence of a fixed factor may create economies of scope in the short run for output levels at which economies of scope do not exist in the long run. In addition, unlike in the long run when economies of scope is the only reason for joint production, in the short run there may be joint production even when economies of scope do not exist. The second condition states that there may be joint production if there are decreasing returns to size for each good produced separately. In this case, the farmer chooses to produce a second good rather than to move up the average cost curve by increasing output of good 1.

The above conditions for joint production give some insight into allocable fixed inputs as a cause of jointness. Allocable fixed inputs can cause jointness insofar as they create economies of scope or decreasing returns to size. It is important to notice that the existence of cost interdependencies ($\partial^2 c^s/\partial y_1 \partial y_2 \neq 0$) (which, as demonstrated in the last section, can be caused by allocable fixed inputs) is not sufficient to imply that joint production will take place. There are two reasons for this: (*a*) As mentiond above, the economies-of-scope condition requries that $\partial^2 c^s/\partial y_1 \partial y_2 < 0$ (if $\partial^2 c^s/\partial y_1 \partial y_2 > 0$ the condition is not met); (*b*) The conditions above are necessary, but not sufficient, conditions. [It is possible for both conditions of the proposition to hold and still to have the inequalities reversed in equation (11).]

The previous section demonstrates that the existence of an allocable fixed input could cause cost interdependence, but that this interdependence could take the form of cost complementarity ($\partial^2 c^s/\partial y_1 \partial y_2 < 0$), creating economies of scope, or of cost anticomplementarity ($\partial c^s/\partial y_1 \partial y_2 > 0$), creating diseconomies of scope. If the fixed input creates diseconomies of scope, far from causing joint production, it may actually work against joint production. If there are diseconomies of scope, then, in order to have joint pro-

[7] Condition (12) is closely related to cost concept which BPW call "transray convexity." A (two-commodity) cost function is transray convex at y if there exists a constant $k \in (0, 1)$ such that, for any $\lambda \in (0, 1)$:

$$\lambda C(y_1/k) + (1-\lambda)C(y_2/(1-k)) \geq C(\lambda \cdot y_1/k, (1-\lambda)y_2/(1-k)).$$

Transray convexity is weaker in one sense and stronger in another sense than condition (12). Condition (12) requires that the transray convexity condition hold along a ray only for $\lambda = k$, not for all $\lambda \in (0, 1)$. However, condition (12) requires that this hold for all rays through y, not just for a single ray.

duction, the decreasing returns to size must be large enough to outweigh the diseconomies of scope.

Using the Multiproduct Cost Function to Test for Causes of Jointness

The last section showed that the existence of allocable fixed inputs could, but would not necessarily, cause joint production. Whether allocable fixed inputs do cause joint production in practice is an empirical question. This section proposes a method of answering that question.

As shown earlier, allocable fixed inputs cannot cause jointness in the long run—in the long run, no inputs are fixed.[8] In the long run, joint production will occur only if there is a technological reason which makes joint production cheaper than nonjoint production (causing economies of scope). Identification of output levels at which jointness is possibly caused by fixed inputs requires an answer to the following question: Are there output levels at which joint production would not be economical in the long run but which might be produced jointly in the short run by firms with fixed inputs? Output levels that would not be produced jointly in the long run are the set of output vectors at which there are no economies of scope with respect to the complete partition in the long-run cost function. Output levels that might be produced jointly in the short run are the set of output vectors at which the necessary conditions for joint production in the short-run cost function are met. This approach will overestimate the range of outputs on which jointness is caused by allocable fixed inputs because this method identifies regions where necessary conditions hold.

SPN argue that because "not all causes of jointness have the same implications for modeling," it is necessary to know the cause of jointness prior to estimating a joint production relation. While this is undoubtedly true when estimating a joint production function, it is not the case when estimating the dual, multiproduct cost function. It is relatively easy to specify a cost function which is sufficiently flexible to permit economies or diseconomies of scope and increasing or decreasing returns to size. BPW discuss this and identify desirable attributes that a cost function should have.

A short-run cost function can be estimated by regressing short-run (annual) cost on levels of output (y) and size of the capital stock (z),

$$c^s = c^s(y|\bar{z}).$$

As pointed out above, the long-run cost function can be derived from the short-run function:

$$C(y) = c^s(y|\bar{z}^*(y)) + w \cdot \bar{z}^*, \quad \text{where } \bar{z}^* = \text{argmin } c^s(\bar{z}) + w\bar{z}.^9$$

The variables c^s, y, and $\bar{z}$ are relatively easy to acquire at a farm level; c^s and y are available from tax returns or income statements; $\bar{z}$ (in value terms) is available from the farm's balance sheet. Estimation of the short-run cost function not only gives directly estimated regions in which economies of scope or diseconomies of size occur in the short run, it also allows construction of a long-run cost function and estimates of output levels for which there are diseconomies of scope in the long run. Leathers includes an application of this method.

The cost function approach to joint production is also attractive for econometric reasons. When allocations of the fixed inputs are observed, econometric efficiency is achieved by estimating a short-short-run cost function subject to allocations being optimal:

$$\partial c^{ss}(y, z_1, \ldots, z_n)/\partial z_i = \partial c^{ss}(y, z_1, \ldots, z_n)/\partial z_j \text{ for all } i \text{ and } j.$$

Furthermore, optimal allocations of allocable variable input k are achieved by calculating $\partial c^s(y_i)/\partial r_k$, where $c^s(y_i)$ is the short-run cost function of producing y_i of commodity i and zero of all other commodities, and r_k is the price of input k. These issues have received considerable attention (Just, Zilberman, and Hochman; Paris; Chambers and Just; Chambers) but are neatly resolved in the cost function approach.

Conclusions

In this paper, the multiproduct cost function concepts introduced by Baumol, Panzar, and

---

[8] Several people reading this paper have commented that in agricultural production there is no long-run, that some inputs such as entrepreneurial ability are always fixed. The debate on this question is more concerned with metaphysics than with economics. Nevertheless, it is a valid criticism of the analysis here that fixed inputs are conceived of as traditional physical capital.

[9] So z^* satisfies $\partial c^s(z^*)/\partial z = -w$ and $\partial^2 c(z^*)/\partial z^2$ is positive semidefinite.

Willig are used to analyze causes of joint production in U.S. agriculture. Although the existence of a fixed input will cause cost interdependency, this does not imply that joint production in the short run will be optimal. Two necessary conditions for joint production in the short run are economies of scope in the short-run production function or diseconomies of size of nonjoint production for at least one of the goods.

Estimation of a short-run cost function will allow empirical examination of the extent to which these necessary conditions hold when jointness is not optimal in the long run. Because jointness cannot be caused by allocable fixed inputs in the long run, this will give an indication of whether or not allocable fixed inputs is an important cause of jointness.

[Received September 1990; final revision received December 1990.]

References

Al-Ayat, R., and R. Färe. "On the Existence of Joint Production Functions." *Naval Res. Logistics Quart.* 26(1979):627–30.

Baumol, Wm., J. Panzar, and R. Willig. *Contestable Markets and the Theory of Market Structure.* New York: Harcourt, Brace, and Jovanovich, 1981.

Carlson, Sune. *A Study on the Pure Theory of Production.* New York: Kelley and Millman, 1956.

Chambers, R. "The Simple Analytics of Nonjoint Production Relations." Dep. Agr. and Resour. Econ. Work. Pap. No. 89-20, University of Maryland, July 1989.

Chambers, Robert, and Richard Just. "Estimating Multioutput Production Relationships." *Amer. J. Agr. Econ.* 71(1989):980–95.

Gorman, I. E. "Conditions for Economies of Scope in the Presence of Fixed Costs." *Rand J. Econ.* 16(1985):431–36.

Just, R. E., D. Zilberman, and E. Hochman. "Estimation of Multicrop Production Functions." *Amer. J. Agr. Econ.* 65(1983):770–80.

Knudsen, Niels. *Production and Cost Models of a Multi Product Firm.* Odense, Denmark: Odense University Press, 1973.

Lau, L. J. "Profit Functions of Technologies with Multiple Inputs and Outputs." *REStat* 54(1972):281–89.

Leathers, Howard. "Allocable Fixed Inputs as a Cause of Joint Production: An Empirical Investigation." Dep. Agr. and Resour. Econ., University of Maryland, 1990.

Lynne, G. D. "Allocable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling: Comment." *Amer. J. Agr. Econ.* 70(1988): 947–49.

Paris, Q. "A Sure Bet on Symmetry." *Amer. J. Agr. Econ.* 70(1988):318–29.

Shephard, R. W. *Theory of Cost and Production Functions.* Princeton NJ: Princeton University Press, 1970.

Shumway, R., R. Pope, and E. Nash. "Allocable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling." *Amer. J. Agr. Econ.* 66(1984):72–78.

——. 'Allocable Fixed Inputs and Jointness in Agricultural Production: Implications for Economic Modeling: Reply." *Amer. J. Agr. Econ.* 70(1988):950–52.

Modeling Interdependence: An Approach to Simulation and Elicitation

Paul L. Fackler

A method for eliciting probability information about jointly dependent random variables and incorporating that information directly in a method for generating simulated random variables is developed. The method is particularly useful in situations in which information on several interdependent variables is required. Applications in agriculture include whole-farm planning with uncertainty about multiple crop yields and prices.

Key words: probability elicitation, risk management, simulation, subjective probability.

Considerable expertise exists for modeling the probabilistic nature of single random variables. Textbooks on simulation generally contain a wealth of techniques for generating random variables from a variety of univariate distributions. Techniques to estimate model parameters are well developed, and considerable progress has been made in developing methods for eliciting subjective distributions.

Less progress has been made, however, in developing models of joint dependence among variables. Most of the joint distributions used in simulation models are highly restrictive, as are existing methods of subjective elicitation. Anderson, Dillon, and Hardaker (chap. 2) suggest two methods for eliciting information concerning dependence relationships among variables. The first method involves the assessment of probability values for a two-way table of intervals. This works well for a two-variable situation but does not extend easily to higher dimensional situations. While bivariate assessments could be elicited for each pair of variables, a method for reconciling the marginal distributions would be needed because each bivariate assessment could yield a different marginal assessment. The second method involves ordering the variables and assessing probability distributions that are conditional on variables higher in the ordering. This task is quite complicated, even for a small number of variables, and requires that the assessor understands conditional probability.

Agricultural economists who develop whole-farm planning decision aids have faced the interdependence assessment problem. Knight, Kubiak, and McCarl review four such computerized aids, two of which handle situations involving joint distributions. The "Whole-Farm Risk-Rating Model" (Anderson and Ikerd) addresses the problem by making strong distributional assumptions (normality of yields and lognormality of prices) to facilitate direct computation of the moments of the net return distribution. The "Agricultural Risk Management Simulator" (ARMS) (King et al.), on the other hand, strives for flexibility in simulating price and yield outcomes, using simulated values to calculate net return probability distributions. In both cases these programs elicit correlation coefficients directly from the user. Knight, Kubiak, and McCarl question whether decision makers can make valid assessments of correlation and suggest using an indirect method.

Questions concerning the ability of humans to articulate probability judgments have received considerable attention, especially by psychologists. Hogarth (1975) points out that most humans have difficulty making subjective probability assessments but that the task is simplified by making it more compatible with human cognitive strategies. In particular, the process should consist of manageable tasks that can be performed sequentially, each of which conforms closely to mental representations already used by the subject.

Paul L. Fackler is an assistant professor in the Department of Agricultural and Resource Economics, North Carolina State University.

Here a method is suggested that elicits joint probability information in a way that is directly usable for simulation. The method frames questions concerning interdependence in terms of simple event probabilities rather than correlations or conditional event probabilities, and it attempts to minimize the time burden imposed on the user. The method involves two steps. In the first, individual marginal distributions for each random variable are elicited. The literature on this topic is extensive (e.g., Spetzler and Stael von Holstein; Anderson, Dillon, and Hardaker). This paper focusses on the second step, in which the dependency relationships are specified. These are parameterized so that the relationship between any two variables is characterized by a single number.

The method developed relies on insights gained from nonparametric approaches to analyzing correlation. These approaches greatly facilitate the generation of interdependent random numbers for simulation analyses, a topic discussed in the next section. The main theme of the paper concerns the median deviation concordance probability and its advantages in subjective elicitation settings. The coherence of the elicited information is then discussed (this section is somewhat technical and may be skipped without loss of continuity) and is followed by some concluding remarks.

Generating Interdependent Random Variables

Functional forms of probability distributions that exhibit flexible marginal distributions, are capable of a wide range of shapes, and show flexible specification of interdependencies are relatively rare. The most commonly used forms that exhibit the latter property are based on some transformation of the normal distribution, such as Johnson's system in which dependent normal variates, denoted by Z, are transformed using one of the functions $X = \ln(Z)$, $X = \ln(Z/(1 - Z))$ or $X = \sinh^{-1}(Z)$ (Johnson and Kotz; Stuart and Ord, p. 234). This approach has a significant advantage over other functional forms in the flexibility with which the interdependencies among variables are represented. These interdependencies are parameterized by the correlation matrix of the underlying normal variables. Many other approaches impose severe limitations on this aspect of the distribution, such as forcing the equality of all correlation coefficients (Johnson).

The Johnson approach, however, does not offer much flexibility in its representation of the marginal distribution. Independently, Li and Hammond, and King developed an approach whereby the marginal distribution could take any arbitrary form. This method maximizes flexibility in the shape of the marginal distribution.

The following problem is posed in these studies: How can random numbers be generated for k interdependent variables with marginal distributions F_i, $i = 1, \ldots, k$, where the F_i are cumulative distribution functions (CDFs)? The proposed solution involves first generating k standard multinormal variables, called Z_i, with correlation matrix R.[1] Random variables, denoted X_i, with the desired marginal distributions can be obtained by transforming these variables according to $X_i = F_i^{-1}(\Phi(Z_i))$, where Φ is the standard normal CDF ($N(0, 1)$). This can be thought of as first transforming the normal variables into uniform ones ($\Phi(Z_i)$) and then using the inverse CDF method for generating random variables. The approach retains the flexibility of the Johnson system in representing interdependency, using one parameter to represent the relationship between each pair of variables.[2]

The main issue associated with this approach is specification of the correlation matrix used to generate the initial multinormal variables. Li and Hammond desire to generate the X_i with a given product moment correlation matrix. To do this they must determine the correlation coefficients of the normal variables, which they call the predistorted coefficients. The determination of the predistorted coefficients is not straightforward because product moment correlation coefficients are not invariant to transformations of the underlying marginal distributions.[3] While Li and Hammond develop a method to address this

[1] Methods for generating normal variates are discussed in Kennedy and Gentle, pp. 201–9 and 228–31.

[2] The random variables generated by this method have joint density function

$$f(x; R) = \prod_i^k f_i(x_i)|R|^{-0.5} \exp(0.5T(x)'(I - R^{-1})T(x)),$$

where f_i denotes the marginal density of the ith variate, R is a $k \times k$ correlation matrix and $T(X) = \Phi^{-1}(F(X)) = Z$.

[3] The problem can be illustrated in the lognormal case. Suppose that $X_1 = \exp(Z_1)$ and $X_2 = \exp(Z_2)$, where Z_1 and Z_2 are standard binormal variates with correlation r. The fact that $\ln(X_1X_2) \sim N(0, 2(1 + r))$ and that, for any lognormal variate, X (i.e., $X = \exp(Z)$ where $Z \sim N(\mu, \sigma^2)$), $E[X^m] = \exp(m\mu + m^2\sigma^2/2)$, can be used to show that the correlation between X_1 and X_2 is given by $r^* = (e^r - 1)/(e - 1)$. The lower bound on r^* occurs at $r^* = -1/e \approx -0.368$ when $r = -1$.

problem, the method is computationally difficult and time consuming. King also recognized the problem but took the view that in many practical applications one could treat the predistorted coefficients as equal to the desired correlations. While simpler than the Li and Hammond method, it is not clear when such an approach would represent an appropriate approximation.

Characterizing Dependency Relationships

The difficulty in determining the appropriate predistorted coefficients can be overcome by using a nonparametric correlation concept. By their nature, nonparametric measures are invariant to transformation of marginals. In the present context, this implies that generating multinormals with a given nonparametric correlation matrix will result in transformed variables with the same correlation matrix.

Perhaps the most familiar nonparametric correlation concept is Spearman's rank correlation, which is the sample analog of the grade correlation (Joag-Dev) defined as

$$E[(F_i(X_i) - 1/2)(F_j(X_j) - 1/2)].$$

One can easily generate multinormal variables with a given rank correlation matrix using the relationship between the rank and the product moment correlations for multinormal variables:

$$r = 2 \sin (\pi c/6),$$

where c is the rank correlation and r is the product moment correlation (Hotelling and Pabst, Joag-Dev).

While this approach represents a solution to the problem of invariance with respect to transformation of marginals, both the rank and product moment correlation concepts suffer from problems in subjective elicitation.[4] Neither of these correlation concepts is intuitive, and even persons trained in probability theory are likely to encounter difficulty in subjectively quantifying their beliefs about interdependence using them.

However, dependence among random variables can be expressed in a variety of ways, some of which are more familiar and understandable than others. Researchers typically elicit subjective probabilities based on an assessment of a histogram, a probability density function (PDF) or a cumulative distribution function (CDF) (Hogarth 1987; Bunn, sec. 7.2). These methods all ask subjects questions about event probabilities. The simpler and more familiar the event, the easier it is for subjects to quantify their beliefs. Probabilistic questions about probabilities of simple, intuitively defined events are preferable to questions concerning joint moments.

Fortunately, the literature on nonparametric correlation measures contains several statistics that have event probability interpretations. Kendall's τ is perhaps the best known of these. It is a measure of the probability that any pair of observations will agree in the sign of the difference between the two variables:

$$\text{Prob}\{(X_{it} - X_{jt})(X_{is} - X_{js}) > 0\},$$

where i and j index variables and t and s index observations. However, this complex event may be difficult to describe and to quantify subjectively. A simpler measure that is both nonparametric and has an event probability interpretation is the median deviation concordance (MDC) probability.

The MDC probability is defined as the probability that two variables will both fall either above or below their respective medians. Formally, this can be written

$$p = \Pr\{\text{MDC}\} = \Pr\{(X_i - m_i)(X_j - m_j) > 0\},$$

where m_i and m_j are the medians of variables X_i and X_j, respectively. If realized values of X_i and X_j are plotted in a scatter diagram with axes intersecting at the medians of the two variables, the median deviations are in concordance for points in the (positive, positive) and the (negative, negative) quadrants. The probability of MDC is the probability weight assigned to those quadrants.

Another way to express this concept is to define a random variable equal to the sign of the median deviation. Let

$$S_i = \text{sign}(X_i - m_i) = \begin{cases} 1 & \text{if } X_i > m_i \\ 0 & \text{if } X_i = m_i, \\ -1 & \text{if } X_i < m_i \end{cases}$$

[4] If the correlation coefficients are estimated from data rather than subjectively elicited, then the issue is not important. In this case, a number of options are available. One can select specific functional forms for the marginal distributions and jointly estimate the parameters of these distributions with the predistorted coefficient matrix. Alternately, one can estimate the parameters of the marginal distributions individually, then transform the variables to normally distributed variables and estimate the product moment correlation of these transformed variables to obtain an estimate of the predistorted coefficients. One could also exploit the rank correlation concept, estimating the rank correlation directly and then calculating the appropriate predistorted coefficients.

and define S_j similarly. The MDC probability can then be written

$$P = \Pr\{S_i S_j = 1\}.$$

Note that $E[S_i] = 0$ and $\text{Var}[S_i] = 1$; hence, the correlation between S_i and S_j is

$$q = E[S_i S_j] = 1p + -1(1 - p) = 2p - 1.$$

The measure q, the sample analog of which was introduced by Blomqvist (see also Joag-Dev), provides an alternative correlation coefficient to those discussed above. It clearly ranges between -1 and 1, with $q = 0$ representing the situation in which the signs of the median deviations are uncorrelated.[5]

With k variables, a $k \times k$ matrix of MDC probabilities must be specified. This matrix is symmetric with unit diagonal. Thus $k(k - 1)/2$ MDC probabilities, one for each pair of variables, define this matrix.

The probability of MDC in the bivariate normal case is

$$p = 0.5 + \sin^{-1}(r)/\pi,$$

where r is the (product moment) correlation (Stuart and Ord, sec. 15.6, p. 482). Note that p equals 0, 0.5, and 1 when r equals -1, 0, and 1, respectively. Alternatively this relationship can be written in terms of the correlation measure:

$$q = 2 \sin^{-1}(r)/\pi.$$

Transforming each MDC probablity separately in a k-variable problem using

$$r = \sin(\pi(p - 0.5))$$

results in a correlation matrix, R, which can be used to generate multinormal random variates.

Subjective Elicitation

A stumbling block in both decision theoretic and simulation models is the elicitation of subjective probability information about dependence among variables. MDC probabilities provide a simple vehicle for eliciting such information because the dependence is characterized by the probability of a clearly defined event. Furthermore, elicitation of each MDC probability involves answering a single question, greatly reducing the number of judgments needed and thereby making feasible elicitations involving a relatively large number of variables. Finally, the information can be incorporated directly into the random number generator so that the random numbers generated correctly exhibit the properties elicited. The assessment procedure proceeds in two stages. First, each of the marginal distributions is assessed. This assessment can occur in any number of ways and does not require that the subject make the distinction between a marginal and a conditional event. The dependence between each pair of variables is then elicited by obtaining a single MDC probability. This can be obtained with a single question concerning an event probability; for example: "You have indicated that there is a 50/50 chance of getting corn yields above or below 110 bushels and soybean yields above or below 30 bushels. What is the probability that yields will either both be above or both be below these levels?"

The method can be reinforced using a graphical presentation. A plot of each pair of variables with axes intersecting at the two medians can be presented to the subject. The MDC probability is the weight associated with the northeast and southwest quadrants. Scatterplots of simulated values also can be presented to the subject to help assess the validity of the measures.

The use of MDC probabilities does not yield a complete representation of the joint probability distribution. In particular, higher cross-moment properties are not assessed. The method, however, does concentrate on events about which most decision makers should be capable of making the most informed judgments.

Once a matrix of MDC probabilities has been elicited, a matrix of predistorted (normal) correlation coefficients can be obtained. Random numbers can then be generated using the method discussed earlier. These random numbers will exhibit the elicited MDC probability matrix, eliminating a source of error in simulations based on subjective assessments.

Coherence of MDC Probabilities

The use of MDC probabilities to elicit dependence relationships encounters two potential problems when three or more variables are being

[5] Blomqvist discusses the asymptotic distribution of the sample correlation measure. He notes that tests of independence based on this statistic in the bivariate normal case have an efficiency of $(2/\pi)^2 \approx 0.41$ relative to tests based on the Pearson product moment correlation coefficient. Thus, as a test statistic, this measure is clearly inferior to tests based on rank correlation (Spearman's ρ) or on pairwise concordance probabilities (Kendall's τ), both of which have an efficiency of $9/\pi^2 \approx 0.91$.

modeled. The first problem concerns the mutual consistency or coherence of a matrix of MDC probabilities (Bessler). In the two-variable case, any number between 0 and 1 can serve as a valid MDC probability. The values that a set of MDC probabilities can take on in higher dimensional situations are restricted. One example of such a restriction rules out cases in which three variables are all mutually highly negatively correlated. Clearly, if two variables always move inversely with a third, when they must vary positively with one another. Thus, the matrix of MDC probabilities cannot be an identity matrix, which assigns 0 probability to any concordance (except in the two-variable case). Similarly, if two variables are highly correlated and a third is largely independent of one of these variables, it must be largely independent of the other. This rules out MDC probability matrices such as

$$P = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix},$$

in which the pairs (1, 2) and (2, 3) are always concordant, but the pair (2, 3) is never concordant. Such an MDC probability matrix is incoherent.

An elicitation procedure must be able to distinguish incoherent assessments from coherent ones. An algorithm for making such a determination can be developed by considering the different possible realizations of the signs of the median deviations. In general, with k variables there are 2^k permutations of signs. Each of these corresponds to an orthant in the variable space when the axes all intersect at the medians of the variables.

These permutations can be written as binary numbers in which the sign of the ith variable is known to be positive if the ith digit (from the right) is a 1. For example, with two variables the four orthants (quadrants) would be labeled

$$\begin{array}{c|c} 10 & 11 \\ \hline 00 & 01 \end{array}.$$

An MDC probability is the sum of the probabilities associated with orthants for which a given pair of variables is concordant (orthants 00 and 11 in the 2-variable case). If the orthant probabilities were known, the appropriate orthant probabilities could be summed to determine the MDC probabilities. Using a consistent method for arranging variables, this process can be written as

$$Aw = p,$$

where p is the set of MDC probabilities written as a vector, w is a vector of orthant probabilities, and A is a matrix with elements $a_{ij} = 1$ if the jth pair of variables is concordant in the ith orthant and $a_{ij} = 0$ otherwise.

The coherence of a candidate p vector is equivalent to the existence of a nonnegative w-vector with elements that sum to 1 (note that w represents a set of probabilities associated with a partitioning set of events). Validation can be carried out using linear programming methods.

Consider minimizing the maximum absolute deviation of Aw from p subject to the constraints on w:[6]

$$\min_{w} \max_{i} |Aw - p|_i \qquad \text{subject to } \Sigma_j w_j = 1 \text{ and } w \geq 0.$$

If a valid w exists, this objective function will be minimized with a value of 0. An explicit formulation of the problem is

$$\min_{d,w} d \text{ subject to } d[1] + Aw \geq p,$$
$$d[1] - Aw \geq -p,\ [1]'w = 1 \text{ and } d,\ w \geq 0,$$

where d is a scalar and [1] is a vector of ones. This problem can be solved using standard LP software (Kennedy and Gentle, pp. 525–28, discuss minimizing maximum deviations). The optimal value of the objective function can be checked and, if greater than zero, the p vector is rejected. (A technical appendix with details on a method for ordering variables and defining A, and computer algorithms implementing the method is available on request from the author).

This linear programming approach also provides an alternative set of MDC probabilities in case the elicited set is incoherent. The value of Aw at the optimal level of w provides the set of coherent MDC probabilities closest to the one elicited (in terms of the maximum absolute deviation metric). This set of probabilities could be suggested to the decision maker as a possible alternative or simply used in place of the elicited set.[7]

A second problem in implementing the simulation method is that not all valid sets of MDC probabilities can be generated by multinormal variables. Thus, even if a matrix of MDC probabilities is coherent, there may be no matrix of

[6] Alternatively, one could minimize the sum of the absolute deviations of Aw from p. Such a procedure can also be implemented in a linear programing framework.

[7] A similar suggestion is made by Nau for a related problem.

predistorted coefficients that can generate variables displaying the implied behavior.

To see this, consider the four-variable case in which the probabilities associated with orthants 0011, 0101, 0110, 1001, 1010, and 1100 are each 1/6 and the ten other orthants have probability 0. This implies the MDC probability matrix

$$\begin{bmatrix} 1 & 1/3 & 1/3 & 1/3 \\ 1/3 & 1 & 1/3 & 1/3 \\ 1/3 & 1/3 & 1 & 1/3 \\ 1/3 & 1/3 & 1/3 & 1 \end{bmatrix},$$

which, in turn, implies R has correlation coefficients all equal to $-1/2$, which is not positive semidefinite (p.s.d.). This case admittedly is odd; it places probability only in those orthants in which two of the variables have the same sign and the other two have the opposite sign.

A practical, though not completely satisfying, solution to this problem is to insist that the set of MDC probabilities be considered valid only if it can be generated by some valid matrix of predistorted coefficients. This latter matrix must be positive semidefinite, a condition that is easily tested. If the elicitation process is conducted using a computer, then the positive semidefiniteness of a matrix of predistorted coefficients associated with a set of MDC probabilities can be tested immediately and the subject can be requested to revise the MDC probabilities if the test fails.

This solution may be less restrictive than it first appears. It is difficult to characterize in a precise way the nature of the valid sets of MDC probabilities not representable by the multinormal distribution. The example given above suggests, however, that these sets are somewhat pathological. In any case, the fact that the beliefs elicited from a subject are directly incorporated into the generation procedure means that those cases in which a subject insists on a set of MDC probabilities that cannot be generated by the method can be easily identified.

Conclusions

This paper presents a general method for handling interdependencies among random variables in simulation studies. The method is simple and flexible, both in conception and implementation. In particular, relatively complex interdependencies among variables can be represented with the relationship between each pair of variables parameterized by a single coefficient. This coefficient has an intuitive interpretation, thereby facilitating subjective elicitation. In addition, random numbers with specified MDC probabilities are easily generated, thereby increasing the accuracy with which assessed information is incorporated in a simulation analysis. The method provides a practical solution to a major stumbling block in the implementation of simulation methods.

[Received August 1990; final revision received December 1990.]

References

Anderson, J. R. "Simulation: Methodology and Application in Agricultural Economics." *Rev. Mktg. and Agr. Econ.* 42(1974):3–55.

Anderson, J. R., J. L. Dillon, and B. Hardaker. *Agricultural Decision Analysis*. Ames: Iowa State University Press. 1977.

Anderson, K. B., and J. E. Ikerd. "Whole-Farm Risk-Rating Microcomputer Model." *S. J. Agr. Econ.* 17(1985):183–87.

Bessler, D. A. "Risk Concepts and Measures for Decision Analysis." *Risk Management in Agriculture*, ed. P. J. Barry. Ames: Iowa State University Press, 1984.

Blomqvist, N. "On a Measure of Dependence Between Two Random Variables." *Ann. Math. Statist.* 32(1950):485–98.

Bunn, D. W. *Applied Decision Analysis*. New York: McGraw-Hill Book Co., 1984.

Hogarth, R. M. "Cognitive Processes and the Assessment of Subjective Probability Distributions." *J. Amer. Statist. Assoc.* 70(1975):271–89.

——. *Judgment and Choice: The Psychology of Decision*, 2nd ed. New York: John Wiley & Sons, 1987.

Hotelling, H., and M. R. Pabst. "Rank Correlation and Tests of Significance Involving No Assumption of Normality." *Ann. Math. Statist.* 7(1936):29–43.

Joag-Dev, K. "Measures of Dependence." *Handbook of Statistics*, vol. 4, ed. P. R. Krishnaiah and P. K. Sen, pp. 79–88. New York: Elsevier Science Publishers, 1984.

Johnson, M. E. *Multivariate Statistical Simulation*. New York: John Wiley & Sons, 1987.

Johnson, N. L., and S. Kotz. *Distributions in Statistics: Continuous Multivariate Distributions*. New York: John Wiley & Sons, 1972.

Kennedy, W. J., Jr., and J. E. Gentle. *Statistical Computing*. New York: Marcel Dekker, 1980.

King, R. P. Operational Techniques for Applied Decision Analysis Under Uncertainty. Ph.D. thesis, Michigan State University, 1979.

King, R. P., J. R. Black, F. R. Benson, and P. A. Pavkov. "Agricultural Risk Management Simulator Microcomputer Program." *S. J. Agr. Econ.* 20(1988):165–71.

Knight, T. O., K. A. Kubiak, and B. A. McCarl. "Incorporating Uncertainty into Extension Decision Aids: An Overview of Four Approaches." *Future Directions in Risk Analysis for Agricultural Production Firms: Proceeding of a Seminar Sponsored by Southern Regional Project S-180; San Antonio, Texas; March 22–25, 1987*, pp. 43–61. Dep. Agr. and Appl. Econ., University of Minnesota, Aug. 1987.

Li, S. T., and J. L. Hammond. "Generation of Pseudorandom Numbers with Specified Univariate Distributions and Correlation Coefficients." *IEEE Transactions on Systems, Man, and Cybernetics*, Sep. 1975, pp. 557–61.

Nau, R. F. "Coherent Assessment of Subjective Probability." Operations Res. Ctr. Res. Rep. ORC 81-5, University of California, Berkeley, 1981.

Spetzler, C. S., and C.-A. S. Stael von Holstein. "Probability Encoding in Decision Analysis." *Manage. Sci.* 22(1975):340–58.

Stuart, A., and J. K. Ord. *Kendall's Advanced Theory of Statistics*, 5th ed. New York: Oxford University Press, 1987.

A Generalized Measure of Farm-Specific Technical Efficiency

Philip J. Dawson, John Lingard, and Christopher H. Woodford

Single measures of farm-specific technical efficiency over time are calculated for rice farms in Central Luzon, the Philippines, from the residuals of a stochastic frontier production function. Panel data from the International Rice Research Institute's periodic "Loop Survey" are used. Results show a narrow range of efficiency between 84% and 95% across the twenty-two farms, so that there is limited scope for increasing output by resource reallocation. A comparison is made with measures of technical efficiency using traditional covariance analysis.

Key words: Philippines, stochastic production frontier, technical efficiency.

Lingard, Castillo, and Jayasuriya; and Dawson and Lingard have measured farm-specific technical efficiency on rice farms in Central Luzon, the Philippines, using IRRI's "Loop Survey." In particular, Lingard, Castillo, and Jayasuriya estimate a production function for thirty-two farms from panel data for 1970, 1974, and 1979 using covariance analysis. Measures of technical efficiency are then calculated from the farm-specific dummy variables. The results show that the least efficient farm achieves only 29% of the output of the most efficient farm for identical input levels. More recently, Dawson and Lingard present estimates of farm-specific technical efficiency from a stochastic frontier production function using data for 1970, 1974, 1979, and 1982. For each year, a cross-section stochastic production function is estimated using the composed error model of Aigner, Lovell, and Schmidt and of Meeusen and van den Broeck. From the residuals, a measure of technical efficiency is then calculated for each farm in each year using the method of Jondrow et al. The results show an even greater range of efficiency than that calculated by Lingard, Castillo, and Jayasuriya: the least efficient farm in all years is in the 10%–19% range, while the most efficient is in the 90%–100% range.

Hall and Bardsley draw attention to the large range of technical inefficiencies obtained by Lingard, Castillo, and Jayasuriya. However, the results substantiate those of Timmer in that covariance analysis often produces large differences in comparative efficiency. This technique tends to bias the production function elasticities downward, with large neutral shifts occurring in the intercept terms of individual farms. The intercept terms thus capture a substantial proportion of the impact of differential input use, leaving little for the factor elasticities to explain. As a result, measures of technical efficiency from covariance analysis tend to be biased downward.[1]

Analysis of covariance was initially used by Timmer as a means of calculating farm-specific technical efficiency.[2] The method overcomes some criticisms associated with estimating deterministic production frontiers by mathematical programming techniques whereby estimates of the residuals provide measures of efficiency

Philip J. Dawson and John Lingard are both senior lecturers in agricultural economics, and Christopher H. Woodford is a computer programming advisor at the University of Newcastle upon Tyne, UK.

The data for this paper were kindly provided by the International Rice Research Institute, the Philippines.

The authors are appreciative of this provision and also acknowledge the contribution and encouragement of John Flinn and Bart Duff of the Department of Agricultural Economics at IRRI. They would also like to thank three anonymous referees for helpful comments on an earlier draft.

[1] This phenomenon is similar to the omission of a managerial input from cross-section production function estimates: specification error biases the estimates of individual production elasticities which, in turn, leads to a downward bias in the estimated returns to scale (Griliches).

[2] Timmer refers to the index of efficiency ratings obtained from covariance analysis as "Hoch's efficiency index" (p. 124). Hoch suggested the use of covariance analysis in estimating production functions as a means of overcoming management bias and estimating "entrepreneurial capacity."

(Farrell).[3] Timmer (p. 124) draws attention to the main difference between the two methods:

> The frontier index is determinate. There is no random error term. The Hoch index is estimated along with an error term. All variation from the frontier is due to efficiency differences according to the frontier measure. Only variation that persists over time is cast into the Hoch measure; all remaining variation is considered part of the random error term. The Farrell frontier . . . is designed to use a single year's cross-section observations. All variation not attributable to differential input use . . . becomes part of the efficiency index. . . . The net result is to cast doubt on the value of an efficiency estimate based on any of the frontier techniques that use only one year's data.

Notwithstanding this criticism, deterministic production frontiers which are estimated statistically and not by mathematical programming methods were subsequently developed (Forsund, Lovell, and Schmidt). In this approach, OLS is used to estimate the average production function, and then the intercept is adjusted upward or corrected until one residual is zero and none of the residuals are positive.[4] Again, estimates of the residuals provide measures of farm-specific technical efficiency so that Timmer's criticisms remain valid. However, with the development of the stochastic frontier production function based on the composed error model of Aigner, Lovell, and Schmidt and of Meeusen and van den Broeck and the subsequent method of calculating firm-specific technical efficiency by Jondrow et al., Timmer's criticisms have now been answered. However, a remaining problem is that the frontier model will have as many efficiency estimates for each firm as there are time periods (Dawson and Lingard). Thus, technical efficiency is somewhat ephemeral, relating only to the technology available in a given year or at a given point in time.

In this paper, we attempt to overcome this criticism. Using panel data from the International Rice Research Institute's periodic "Loop Survey" for a subsample of twenty-two rice farms in Central Luzon, the Philippines for 1970, 1974, 1979, 1982, and 1984, we estimate a stochastic frontier production function embodying a composed error term.[5] The residuals are then used to calculate a single measure of technical efficiency for each farm over the whole fifteen-year period. These results are then compared with those obtained from covariance analysis.

Except for Kalirajan and Shand, our use of a stochastic frontier production function contrasts with previous studies. In particular, we assume that technical efficiency persists and is enduring over time; common sense and intuition suggest that farmers who use today's technology more efficiently than others are likely to use tomorrow's technology more efficiently also.[6] Efficiency differentials should be fairly enduring over a fifteen-year time span. Accordingly and in keeping with Lingard, Castillo, and Jayasuriya, we return to the spirit of Timmer and examine and evaluate farm-specific technical efficiency over time.

Statistical Model and Estimation Procedure

Following Pitt and Lee, consider a stochastic production function model with multiplicative disturbances of the form:

$$y = f(x)e^{\varepsilon}, \tag{1}$$

where y is observed output, x is a vector of inputs and ε is a stochastic error term. Aigner, Lovell, and Schmidt; and Meeusen and van den Broeck specify the error term as being composed of two independent elements:

$$\varepsilon = u + v. \tag{2}$$

The symmetric component, v, permits random variation in output resulting from factors outside the control of the farm like weather, disease, and so on. The one-sided component, $u \leq 0$, reflects technical efficiency relative to the stochastic frontier, $f(x)e^{v}$. Thus $u = 0$ for any farm's output lying on the frontier and is strictly negative for any output lying below the frontier.

The model can be generalized to consider cross-section and time-series data. Assuming that the production can be represented by a log-linear function, combining (1) and (2) gives a variance components model of the form

$$y_{it} = \beta_o \prod_{k=1}^{m} x_{itk}^{\beta_k} e^{(u_{it} + v_{it})}, \tag{3}$$

where x_{itk} is the kth input ($k = 1, \ldots, m$) of the ith farm ($i = 1, \ldots, n$) in time period t ($t = 1$,

[3] See Timmer (pp. 123–34) for a comprehensive list of these criticisms and Forsund, Lovell, and Schmidt for a survey of frontier production functions.

[4] The term, "corrected OLS" or COLS has been used to describe this technique.

[5] While the "Loop Survey" has 61, 57, 143, and 135 observations for 1970, 1974, 1979, and 1982, only 22 were available for 1984.

[6] However, see Schmidt (pp. 312–13) for a contrary view.

$\ldots, T$). A measure of farm-specific technical efficiency is given by

$$(4) \qquad e^{u_{it}} = \frac{y_{it}}{f(x_{itk})e^{v_{it}}},$$

that is, the ratio of observed output to the maximum achievable stochastic level given that technical efficiency is fully realized.

The coefficients β_o, β_k ($k = 1, \ldots, m$) and measures of technical efficiency can be estimated once distributions for u and v are assumed. Following Aigner, Lovell, and Schmidt; and Meeusen and van den Broeck, assume that v is normal; that is, $v \sim N(0, \sigma_v^2)$ and u half-normal, that is $u \leq 0$, $u \sim |N(0, \sigma_u^2)|$. The production function in (3) can now be estimated by maximum likelihood methods. Pitt and Lee use an algorithm requiring the specification of first derivatives only. However, we use both first and second derivatives so that all the information in the data can be maximized. This technique has greater power than Pitt and Lee's technique and results in more reliable and efficient convergence to the maximum. Moreover, there is no need to specify precise starting values for the parameters.[7]

Farm-specific technical efficiency in (4) depends upon the decomposition of ε. Assuming that the technical efficiency of each farm is the same between time periods, define the efficiency of a particular farm as $E[u \mid \bar{\varepsilon}]$:

$$(5) \qquad E[u \mid \bar{\varepsilon})] = \int_{-\infty}^{0} uF(u \mid \bar{\varepsilon})du,$$

where

$$(6) \qquad \bar{\varepsilon} = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_t,$$

and $F(.)$ is the conditional density function of u given $\bar{\varepsilon}$, that is, $F(u \mid \bar{\varepsilon}) = F(u, \bar{\varepsilon})/F(\bar{\varepsilon})$, where $F(u, \bar{\varepsilon})$ and $F(\bar{\varepsilon})$ are the joint probability density function of u and $\bar{\varepsilon}$ and the probability density function of $\bar{\varepsilon}$, respectively. Now, in similar notation to (6), we have

$$(7) \qquad \bar{\varepsilon} = u + \bar{v}.$$

Since v_t ($t = 1, \ldots, T$) is normally distributed, then $v \sim N(0, \sigma_v^2/T)$. It follows that the joint density function of u and $\bar{v}$ is given by

(8)
$$F(u \mid \bar{v}) = \frac{2}{\sqrt{2\pi\sigma_u}} e^{-(1/2u^2/\sigma_u^2)} \frac{\sqrt{T}}{\sqrt{2\pi\sigma_v}} e^{-(T/2\bar{v}^2/\sigma_u^2)}.$$

Substituting (7) into (8) and rearranging gives

$$F(u, \bar{\varepsilon}) = \frac{\sqrt{T}}{\pi\sigma_u\sigma_v} e^{-1/2(u^2/\sigma_u^2+\{T(\bar{\varepsilon}-u)^2\}/\sigma_v^2)}.$$

$F(\bar{\varepsilon})$ is now given by $F(\bar{\varepsilon}) = \int_{-\infty}^{0} F(u, \bar{\varepsilon})du$, which can be written as

(9)
$$F(\bar{\varepsilon}) = \frac{\sqrt{T}}{\pi\sigma_u\sigma_v} \sigma\sqrt{2\pi}\, e^{(\{-\bar{\varepsilon}^2\sigma^2T/2\sigma_u^2\sigma_v^2\}\{1-\Phi(T\sigma\bar{\varepsilon}/\sigma_v^2)\})},$$

where $\sigma^2 = \sigma_u^2\sigma_v^2/T\sigma_u^2 + \sigma_v^2$ and $\Phi(.)$ is the cumulative standard normal distribution function. Returning to the evaluation of (5),

$$(10) \quad \int_{-\infty}^{0} uF(u, \bar{\varepsilon})du$$

$$= \frac{\sqrt{T}}{\pi\sigma_u\sigma_v} e^{(-\bar{\varepsilon}^2\sigma^2T/2\sigma_u^2\sigma_v^2)} \int_{-\infty}^{0} ue^{(-1/2\sigma_u^2\{u-\bar{\varepsilon}\sigma^2T/\sigma_v^2\}^2)}du.$$

Using a standard integral to evaluate (10), dividing by (9) to obtain (5), technical efficiency is given by

$$(11) \qquad E[u \mid \bar{\varepsilon}] = Z - \frac{\sigma\phi\left(\frac{\alpha}{\sigma}\right)}{1 - \Phi\left(\frac{\alpha}{\sigma}\right)},$$

where $Z = \sigma^2/\sigma_v^2 \sum_{t=1}^{T} \varepsilon_t$ and $\phi(.)$ is the standard normal density function. Equation (11) corrects the error in Kalirajan and Shand [eq. (11)]. Since $u \leq 0$, then $0 \leq e^u \leq 1$. The population mean level of technical efficiency is given in Pitt and Lee as

$$(12) \qquad E[e^u] = 2e^{(\sigma_u^2/2)}\{1 - \phi(\sigma_u)\}.$$

Data and Model Specification

Time-series data on changes in farming practices in developing countries are scarce, but IRRI has monitored two sets of Philippine rice producers since 1966. The data used in this study come from one of these—the "Central Luzon Loop Survey"—which details information on rice production practices on the same farms on a highway loop north of Manila in Central Luzon. The survey respondents are dispersed geograph-

[7] A derivation of the likelihood function for this model is available from the authors.

ically over a 200-mile area, but all cultivate rice fields close to a major highway. Data are obtained by two interviews conducted each season with farm operators, one following transplanting and one post-harvest. Herdt discusses some of the main changes that have occurred at farm level.

The data used in this paper consist of a subsample of twenty-two identical farms in 1970, 1974, 1979, 1982, and 1984. Wet-season data only are considered and analyzed. All the farms plant modern rice varieties (MVs) with IR36 the most common variety.[8] Except for the typhoon-affected year of 1974, yields in general increased steadily over the period from 2,738 kilograms per hectare in 1970 to 4,570 kilograms per hectare in 1982. Since then, in the Philippines, rice yields have displayed a slightly negative trend and fell to 3,621 kilograms per hectare in 1984 for this sample. All farms have used increasing amounts of inorganic fertilizers, from 32 kilograms per hectare in 1970 to 62 kilograms per hectare in both 1982 and 1984, and almost all farmers were applying some insecticides. Many were using herbicides, too. By 1984, over two-thirds of the area covered by the twenty-two farms was annually double cropped with rice. Labor use is a changing mixture of hired and family labor, with an initial substitution of hired for family labor between 1970 and 1974 gradually shifting back toward family labor thereafter which, in 1984, provided about 40% of the total farm labor. Transplanting, harvesting, and threshing are mainly done by hired labor, but other activities are carried out by both family and hired workers. Total labor use has fallen from a peak in 1974 of fifty-nine man-days per hectare to forty-six man-days per hectare in 1984.

Before 1973, most of the farms were sharecropped, but subsequent land reform converted the tenancies to leaseholds with the rice farmers paying a fixed rent in kind. A further stage of land reform has also occurred whereby the tenants receive a certificate of land transfer converting them into amortizing land owners purchasing their farms over a fifteen-year period. This changing land tenure accounts for the changing size of farms from an average of 2.82 hectares cultivated in 1970 to 1.83 hectares in 1984. It also partly explains the changing pattern of machinery use on the farms. In the 1960s, four-wheel tractors and large rice-threshing machines were predominant as landlords controlled the harvesting operations to ensure that they obtained their rent in the form of crop share. With the shift to leaseholding, it was unnecessary for landlords to supervise threshing, and small portable threshers were developed and introduced in the mid-1970s. Similarly, two-wheel power tillers replaced large tractors, although secondary tillage operations (harrowing and levelling) are still carried out using water-buffalo.

Changing price relationships in the 1980s in the Philippines have reduced the economic incentives for rice farmers and contributed to the lowering of recorded yields. Real rice prices have declined; paid out costs by farmers as a proportion of the value of production have risen over time as material input prices and hired capital charges increased. Factor prices, especially land and labor, are expected to rise in the long term as a result of increasing cropping intensities and off-farm employment opportunities. The real price of rice is also expected to continue to decline on world markets, and net returns to rice producers on this technological treadmill will continue to stagnate. The economic prospects for Philippine rice farmers are thus not good, and it is therefore essential to determine the extent of the efficiency gap between "best" and "average" farmers and attempt to narrow it in order to maintain rice production levels and to defend farmers' incomes.

The production function for rice is estimated on a whole-farm basis. Output (y) is defined as the physical amount (kgs.) of rice produced. There are four inputs, three of which are measurable and one which is qualitative. The measurable inputs are area (A) measured in hectares, pre-harvest labor (L) measured in man-days, and kilograms of inorganic fertilizer (N).[9] The qualitative input, represented by a dummy variable, is irrigation (D_I) where $D_I = 1$ for irrigated (pump or gravity) and $= 0$ for rain-fed.[10] In addition,

[8] The switch to modern varieties across the wider "Loop Survey" (149 farms) had been completed by 1979.

[9] Nonessential chemicals are excluded from the production function: IR36 is both disease and pest resistant so that use of agrochemicals implies a problem. Accordingly, it is expected that farm yields will be low if chemicals are being used, and it is reasonable to assume tht such inputs do not have the conventional production response. Indeed, no significant effect on rice output could be found for chemical inputs in the form of weedicides or insecticides.

[10] Dummy variables representing mechanization and soil texture were initially included in the production function but then omitted. For the mechanization dummy, results substantiate those previously obtained in that no significant effect on rice output could be found for two-wheel power tillers or four-wheel tractors. Data on "soil texture" were divided into three: clay, clay/loam, and sandy/silty. Clay soils generally lead to higher productivity of wetland rice production. Using clay as the base, perverse (positive) signs on the clay/loam and sandy/silty dummies were obtained, a result similar to that obtained by Herdt and Mandac. Such a result is counterintuitive.

time-specific dummies are included to account for interyear differences (D_t) where D_{74}, for example, is the time dummy for 1974.

The functional form chosen was derived experimentally using OLS prior to eventual estimation by maximum likelihood methods. A transcendental logarithmic function was estimated at first, but serious multicollinearity problems among the cross-product terms led us to prefer a Cobb-Douglas specification. The production function to be estimated is

$$(13)\qquad \ln y_{it} = \beta_o + \beta_1 \ln A_{it} + \beta_2 \ln L_{it} + \beta_3 \ln N_{it} + \beta_4 D_{Iit} + \sum_{j=2}^{T} \gamma_j D_{jit} + \varepsilon_{it},$$

where $i = 1, \ldots, n$; $t = 1, \ldots, T$; $D_{jit} = 1$ if $j = t$, and $= 0$ otherwise.

Results

The estimated stochastic production frontier is

$$\ln \hat{y}_{it} = \underset{(53.29)}{6.818} + \underset{(22.00)}{0.753} \ln A_{it} + \underset{(7.08)}{0.216} \ln L_{it} + \underset{(8.93)}{0.055} \ln N_{it} + \underset{(10.26)}{0.268}\ D_{Iit} - \underset{(11.18)}{0.401}\ D_{74} + \underset{(7.23)}{0.266}\ D_{79} + \underset{(10.80)}{0.408}\ D_{82} + \underset{(5.47)}{0.208}\ D_{84},$$

where log-likelihood is -52.48, $\hat{\sigma}_u^2 = \underset{(2.05)}{0.020}$, $\hat{\sigma}_v^2 = \underset{(30.62)}{0.146}$, and asymptotic t-statistics are in parentheses. All coefficients on the variables are significant and accord with prior beliefs as to their various influences on rice production; namely, the production elasticities are positive and less than unity. The time dummies are positive except for 1974, when abnormal typhoon damage lowered the rice harvest considerably. The positive time dummies reflect an upward drift of technology over time, improved farmer learning, and so on. The irrigated farms not surprisingly obtain higher output levels than the rainfed ones, as implied by the positive and significant coefficient on the irrigation dummy. There is a small but significant fertilizer effect; the labor input is important; and, as with previous studies, the influence of land on farm-level rice output is dominant. The validity of the measures of technical efficiency subsequently computed rest upon the estimates of the production function; we are convinced that our estimated production function is a good one both in terms of plausibility and statistical properties. Indeed, it is much better than our other previous published results (Lingard, Castillo, and Jayasuriya; Dawson and Lingard).

Table 1 and figure 1 present the frequency distribution and probability histogram of the technical efficiency ratings. A range of efficiencies is observed across the twenty-two farms; but the spread is not large, with the best farm being over 95% efficient while the worst is only 84% efficient. Fourteen farms are 90% or more efficient, and three are less than 85% efficient. The mean efficiency and the median from the sample is 89.3% and 89.5%, respectively; the population mean efficiency from (12) is 89.7%. There is no significant evidence of skewness or kurtosis; the distribution is mesokurtic, that is, neither flat nor peaked with respect to the general appearance of the frequency curve.

A critical assumption of the analysis is that technical efficiency is time invariant. In principle, it is possible to test this assumption; but, as noted by Pitt and Lee (model III), "[this] is precluded because of the difficulty in specifying

Table 1 Frequency Distribution of Technical Efficiency Ratings

Efficiency Rating (%)	Number of Farms: Stochastic Frontier	Covariance Analysis
95–100	1	1
90–94.9	9	
85–89.9	9	
80–84.9	3	1
75–79.9		1
70–74.9		1
65–69.9		1
60–64.9		3
55–59.9		4
50–54.9		4
45–49.9		3
40–44.9		2
35–39.9		1
0–34.9		
Mean	89.33	58.61
Standard deviation	3.32	14.66
Median	89.47	57.61
Coefficient of skewness	−0.055 (0.491)	1.063 (0.491)
Kurtosis	−1.066 (0.953)	1.730 (0.953)

Note: Standard errors are in parentheses.

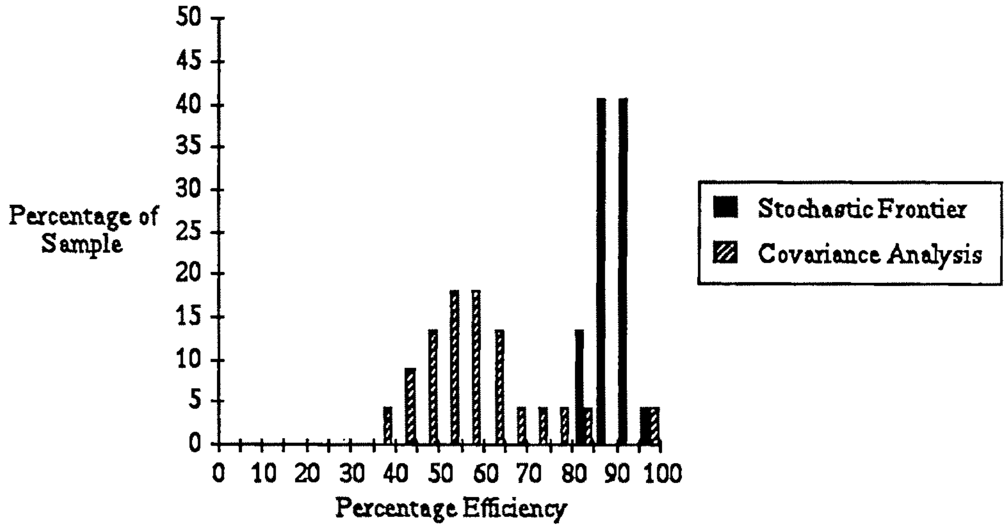


Figure 1. Probability histogram of the efficiency ratings

a flexible multivariate distribution $(u_{i1}, \ldots, u_{iT})$ with each $u_{it} \le 0$. The multivatiate truncated normal distribution is a possible candidate but the implied likelihood function is computationally intractable" (pp. 47–48). A key issue here is the provision of a useful algorithm for evaluating T-dimensional integrals of cumulative normal distribution functions. In general, currently available algorithms are too time consuming to be repeatedly invoked in a conventional minimization procedure. An alternative is to follow Dawson and Lingard and calculate farm-specific efficiency ratings from year-specific cross-section data using maximum likelihood methods. This is impractical with the small data sets of twenty-two because of convergence problems. These results are not compared with those using covariance analysis.

Covariance Analysis

The equation to be estimated using covariance analysis is (13), where the error term, ε_t, is replaced by v_t and a set of farm-specific dummy variables, D_i, is included. The additional terms are $\Sigma_{s=2}^{n} \lambda_s D_{sit}$, where $D_{sit} = 1$ if $s = i$, and $=$ 0 otherwise. By setting the base as the most efficient farm, the estimates of λ_s $(s = 2, \ldots, n)$ and $\lambda_1 = 0$ are used to calculate the technical efficiency for each farm, $0 \le e^{\lambda} \le 1$: the best farm is 100% efficient, and those of all others are measured in relative terms. The estimated equation is

$$\begin{aligned}
\ln \hat{y}_{it} = {} & \underset{(13.05)}{6.590} + \underset{(4.70)}{0.695} \ln A_{it} + \underset{(2.12)}{0.233} \ln L_{it} \\
& + \underset{(0.75)}{0.020} \ln N_{it} + \underset{(1.66)}{0.216}\, D_{Iit} - \underset{(3.16)}{0.385}\, D_{74} \\
& + \underset{(2.18)}{0.280}\, D_{79} + \underset{(3.28)}{0.442}\, D_{82} + \underset{(1.65)}{0.227}\, D_{84} \\
& + \sum_{s=2}^{n} \hat{\lambda}_s D_{sit} \qquad R^2 = 0.81
\end{aligned}$$

(t-statistics in parentheses). The signs and magnitudes of all coefficients are similar to those obtained from the stochastic frontier approach, although those on fertilizer and the irrigation and 1984 time dummies are now insignificant; over 81% of the variation in the (log of) output is explained. Table 1 and figure 1 again present the frequency distribution and probability histogram of the technical efficiency ratings. The mean efficiency and the median from the sample are 58.6% and 57.6%, respectively. The range of efficiencies across the twenty-two farms is large with the worst producing only 36% of the output of the best, given identical input levels. These results substantiate those of Lingard, Castillo, and Jayasuriya in that covariance analysis produces large differences in comparative efficiency. The coefficient of skewness implies that the distribution of efficiency ratings is positively and significantly skewed, but there is no evidence of kurtosis.

It is clear from table 1 and figure 1 that the distributions of efficiencies obtained from both

stochastic frontier and covariance analysis approaches are different; potential gains in technical efficiency are small for the former but are relatively large for the latter. Intuitively, measures of inefficiencies obtained from covariance analysis are too large to be maintained over time; those obtained from the stochastic frontier are preferred. Nevertheless, Spearman's correlation coefficient of 0.95 implies that there is a significant relationship between the rankings of technical efficiencies from the two approaches.

Conclusions

The responsibility for technical inefficiency rests mainly with management. As Liebenstein (p. 397) notes: "Managers determine not only their own productivity but the productivity of all cooperating units in the organization." Because it is reasonable to assume that management is fixed over a short period of time, it therefore follows that technical efficiency is fixed also; that is, technical efficiency is persistent and enduring over time. However, most previous studies which measure firm-specific efficiency from stochastic frontier production functions involve the use of year-specific cross-section data. But there are as many efficiency measures for each firm as there are time periods, implying that technical efficiency relates only to the technology available in a given period: it is nondurable and transient.

With nonexperimental data, there is no method of validating measures of technical efficiency, rather they depend upon the production function estimates.[11] In comparison with previous studies using similar data (Lingard, Castillo, and Jayasuriya; Dawson and Lingard), the results presented here compare favorably, and the measures of technical efficiency accord more with intuition. We conclude that this small sample of Philippine rice farmers has adopted the new technology rapidly between 1970 and 1984, and all have quickly adapted their farming practices at a similar rate. There are no technological laggards within the sample, and significant yield gaps do not exist between best- and average-practice farmers. Accordingly, there is little purpose in attempting to relate the very narrow spread of farm-specific inefficiencies to farm-specific socioeconomic factors like age of the farmer, education, tenancy, access to credit, and so on. Increased rice production in the future, then, must come from further technological progress.

[Received August 1989; final revision received January 1991.]

[11] In this context, see Herdt and Mandac, who compare production functions from experimental and nonexperimental data.

References

Aigner, D., C. A. K. Lovell, and P. Schmidt. "Formulation and Estimation of Stochastic Production Function Models." *J. Econometrics* 6(1977):21–34.

Dawson, P. J., and J. Lingard. "Measuring Farm Efficiency Over Time on Philippine Rice Farms." *J. Agr. Econ.* 40(1989):168–77.

Farrell, M. J. "The Measurement of Productive Efficiency." *J. Royal Statist. Soc.* 120(III)(1957):259–75.

Forsund, F. R., C. A. K. Lovell, and P. Schmidt. "A Survey of Frontier Production Functions and of Their Relationship to Efficiency Measurement." *J. Econometrics* 13(1980):5–25.

Griliches, Z. "Specification Bias in Estimates of Production Functions." *J. Farm Econ.* 39(1957):8–20.

Hall, N., and P. Bardsley. "Dummy Variable Estimators of Technical Efficiency: A Comment." *J. Agr. Econ.* 38(1987):335–39.

Herdt, R. W. "A Retrospective View of Technological and Other Changes in Philippine Rice Farming 1965–82." *Econ. Develop. and Cultur. Change* 35(1987):329–49.

Herdt, R. W., and A. M. Mandac. "Modern Technology and Economic Efficiency of Philippine Rice Farmers." *Econ. Develop. and Cultur. Change* 29(1981):375–99.

Hoch, I. "Estimation of Production Function Parameters Combining Time-Series and Cross-Section Data." *Econometrica* 30(1962):34–53.

Kalirajan, K. P., and R. T. Shand. "A Generalized Measure of Technical Efficiency." *Appl. Econ.* 21(1989):25–34.

Liebenstein, H. "Allocative Efficiency vs. 'X-Efficiency'." *Amer. Econ. Rev.* 56(1966):392–415.

Lingard, J., L. Castillo, and S. K. Jayasuriya. "Comparative Efficiency of Rice Farms in Central Luzon, the Philippines." *J. Agr. Econ.* 34(1983):63–73.

Jondrow, J., C. A. K. Lovell, I. S. Materov, and P. Schmidt. "On the Estimation of Technical Efficiency in the Stochastic Production Function Model." *J. Econometrics* 19(1982):233–38.

Meeusen, W., and J. van den Broeck. "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error." *Int. Econ. Rev.* 18(1977):435–44.

Pitt, M. M., and L.-F. Lee. "The Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry." *J. Develop. Econ.* 9(1981):43–64.

Schmidt, P. "Frontier Production Functions." *Econometric Rev.* 4(1986):89–328.

Timmer, C. P. "On Measuring Technical Efficiency." *Food Res. Inst. Stud.* 9(1970):99–171.

Planting Flexibility and Land Allocation

Paul C. Westcott

Break-even price relationships between competing crops are derived to illustrate how planting flexibility alternatives affect planting choices. The primary factor differentiating among flexibility alternatives is whether deficiency payments are linked to planting choices. If they are, target prices, program yields, and, in some cases, acreage reduction programs affect net returns comparisons and crop competition. Deficiency payments may be separated from the planting decision on some land either by removing deficiency payments for the acreage involved or by continuing them regardless of the crop planted. Planting choices then would be based on expected net returns from the marketplace.

Key words: break-even prices, farm bill, net returns, planting flexibility.

The amount of flexibility in farmers' planting decisions has been influenced by different farm bills. The Food Security Act of 1985 encouraged producers to plant their historic program crops, thereby diminishing responses to market signals in planting decisions. As a result, a major emphasis in the 1990 farm bill discussions was planting flexibility. Planting flexibility reduces the influence of program benefits on crop choice, thus providing greater responsiveness to market signals.

In this article, a general analytical framework is developed to examine planting flexibility alternatives. Break-even price relationships between competing crops are derived to illustrate how the flexibility alternatives influence land allocation.

Program Barriers to Planting Flexibility

The Food Security Act of 1985 established two barriers that limited planting flexibility—rules for protecting acreage bases for program crops and deficiency payments for target price crops.[1]

Acreage Base Protection

Under the Food Security Act of 1985, acreage bases for most target price crops were equal to a five-year average of previous acreage planted and considered planted to the crop.[2] For upland cotton and rice, any years with no planted and considered planted acreage could be omitted from the five-year calculation if the resulting base calculation did not exceed the average of planted and considered planted acreage in the previous two years.

These acreage base formulas constrained planting flexibility by imposing significant costs if an alternative crop were planted. If a farmer planted an alternative crop on existing base acreage, the farmer would need to forgo participation in subsequent years to reestablish the original acreage base. Otherwise, the farmer would experience a long-run permanent base loss of one-third of the original acreage base that was planted with the alternative crop (Glauber).

Deficiency Payments for Target Price Crops

Deficiency payments for target price crops were large under the Food Security Act of 1985. Target prices under the act were initially held con-

Paul C. Westcott is an agricultural economist with the Economic Research Service, U.S. Department of Agriculture.

The views are the author's and do not necessarily represent those of the Economic Research Service or the U.S. Department of Agriculture.

The author thanks C. Edwin Young, Robert Reinsel, James Schaub, and two *Journal* referees for their many helpful comments on earlier drafts of this article.

[1] Additional policy factors that can affect the crop mix and limit planting flexibility include fixed program yields and payment limitations.

[2] In some cases, acreage that was not planted to a particular program crop may be considered planted to that crop in order to protect a farmer's acreage base. Examples of such land uses include acres idled to comply with an ARP, acres enrolled in 0–92 or 50–92 programs, and acres prevented from being planted by weather.

stant with subsequent small reductions. However, loan rates were reduced sharply, allowing market prices to fall and deficiency payment rates to rise.

Reductions in market prices for target price crops would make other crops more competitive in farmers' planting decisions if acreage allocations were based only on market returns. However, the additional revenues from current and future deficiency payments for program participants restrained switching from and among target price crops. Thus, farm program benefits have encouraged farmers to continue to plant their original mix of target price crops.

Planting Flexibility Alternatives

Any policy designed to increase planting flexibility must alter the acreage base protection rules to preserve the base history when allowable substitute crops are planted. Some flexibility alternatives keep program benefits in planting decisions, thereby providing farmers only partial flexibility to respond to market signals. Other alternatives provide additional flexibility by allowing acreage allocation decisions to be based on expected market returns rather than on farm program benefits.

Five flexibility alternatives are considered in this article. Three alternatives keep farm program benefits in the planting decision, with differences related to how deficiency payments influence the planting choice and whether the land required to be idled is linked to the planting choice. The remaining alternatives separate program benefits from planting decisions on some land.

0–25 Flexibility

Under 0–25 flexibility, plantings of approved alternative crops are allowed on permitted acres of a target price crop. Deficiency payments for the original target price crop are forgone on any switched acreage. In the most general form of 0–25 flexibility, however, acreage switched to an alternative target price crop would receive deficiency payments for that crop.[3]

Farm program benefits remain in the planting decision for 0–25 acreage because deficiency payments are paid only if a target price crop is planted. Acreage reduction program (ARP) provisions for the original target price crop do not affect the planting choice under 0–25 flexibility because the choice is for permitted acreage after compliance with the ARP. Examples of this type of flexibility are the 0–25 flexible plantings provision for soybeans in 1990 and the 10–25 flexible plantings provision for soybeans and sunflowers in 1989.

Set-Aside Program Flexibility

Some flexibility alternatives provide deficiency payments for plantings if a target price crop is planted, as under 0–25 flexibility, but link the ARP acreage requirements to the program provisions for the crop planted. No deficiency payments occur for a non-target price crop, but each acre may be fully planted. As under 0–25 flexibility, farm program benefits remain in the planting decision. In contrast, however, the planting decision at the margin is based on an ARP-adjusted acre planted to each competing target price crop or a full acre planted to a competing non-target price crop. An example of this type of flexibility is the set-aside program under the Food and Agriculture Act of 1977. This program allowed farmers to plant target price crops in any proportions as long as the land idled complied with the corresponding set-aside rates. Deficiency payments corresponded to the acreage planted to each target price crop.

Modified Contract Flexibility

The modified contract is another flexibility alternative that keeps farm program benefits in the planting decision. Farmers can plant more than their permitted acreage base but with a loss of deficiency payments on a matching acre for every acre planted above the permitted base. Acreage competition is based on full planted acres of alternative crops. This type of flexibility was introduced for the 1990 wheat crop by allowing farmers to modify their wheat program contracts to plant and harvest up to 105% of their wheat acreage base.

Triple Base Flexibility

The greatest flexibility is provided under alternatives which separate program benefits from planting decisions. Triple base flexibility elim-

[3] A more restricted form of 0–25 flexibility would eliminate deficiency payments for any acreage switched, even if another target price crop is planted.

inates deficiency payments on the acreage involved regardless of whether the original target price crop is planted. A farmer's acreage base for each target price crop is divided into three parts—idled land required to comply with the crop's ARP, supported program crop plantings on part of permitted acreage, and an unsupported third part. Farmers would receive no deficiency payments on the third part of the acreage base, but they could plant approved alternative crops on those acres.

Administration's Flexibility Proposal

Program benefits can also be separated from planting decisions by maintaining deficiency payments for the original target price crop on the acreage involved whether that crop or another crop is planted. In the administration's flexibility proposal (U.S. Department of Agriculture), crop substitutions are allowed on permitted acreage of each crop's base but are limited to wheat, feed grains, cotton, rice, and oilseeds.

Analytical Framework

To analyze the flexibility alternatives, a single-period net returns framework is used, with net returns equaling market and farm program revenues minus variable production costs. Only variable production costs are considered because this analysis focuses on the short-run planting decision. This framework abstracts from other factors that could influence planting choices; examples are yield risk, program payment limitations, multiperiod benefits of crop rotations, and current and multiperiod benefits of maintaining idled land in conserving uses. These considerations can be viewed as adjustments to current costs and, thus, incorporated into the single-period net returns framework.

For each flexibility alternative, equations for net returns per acre are presented for both target price crops and non-target price crops. Break-even price relationships are then derived from pairwise net returns comparisons to illustrate how different planting flexibility alternatives affect the planting decision. These break-even relationships are pairings of prices for competing crops that equate their expected net returns. For a given price expectation for one crop, expected prices for a competing crop above the break-even level would favor its planting, while expected prices for the competing crop below the break-even level would favor the former crop.

Analysis of Flexibility Alternatives

In the following sections, characteristics of flexibility alternatives are first illustrated by break-even relationships for the planting choice between a target price crop and a non-target price crop, followed by break-even relationships involving two target price crops.

0–25 Flexibility

Under 0–25 flexibility, expected net returns per acre for planting a non-target price crop on permitted acreage of a target price crop would equal market revenues from its production minus the corresponding variable costs of production. In equation (1), expected net returns (NRN) for the non-target price crop equal expected price (PN) times expected per-acre yield (YN) minus variable costs of production (VCN) for the non-target price crop.

$$(1) \qquad NRN = PN(YN) - VCN.$$

If the farmer plants the target price crop instead of the alternative non-target price crop on an acre, expected net returns (NRT) would be expected price for the target price crop (PT) times its expected per-acre yield (YT), plus deficiency payments on the program yield, minus the per-acre variable costs of production (VCT) for the target price crop.[4] Equation (2) shows this net returns definition. Deficiency payments are paid on the program yield for the target price crop (PYT) at a payment rate, if positive, that equals the target price (T) minus the market price for that crop. The difference between equations (1) and (2) is the inclusion of deficiency payments for the target price crop.

$$(2) \qquad NRT = PT(YT) + PYT\,[\max(0, T - PT)] - VCT.$$

Figure 1 illustrates how 0–25 flexibility affects break-even price relationships between a target price crop and a non-target price crop. For each price plotted on the horizontal axis for the target

[4] To simplify the analysis, net returns for target price crops are considered only for price expectations above loan rates. This factor is not a major limitation, however, because loan rates for most program crops are well below market prices.

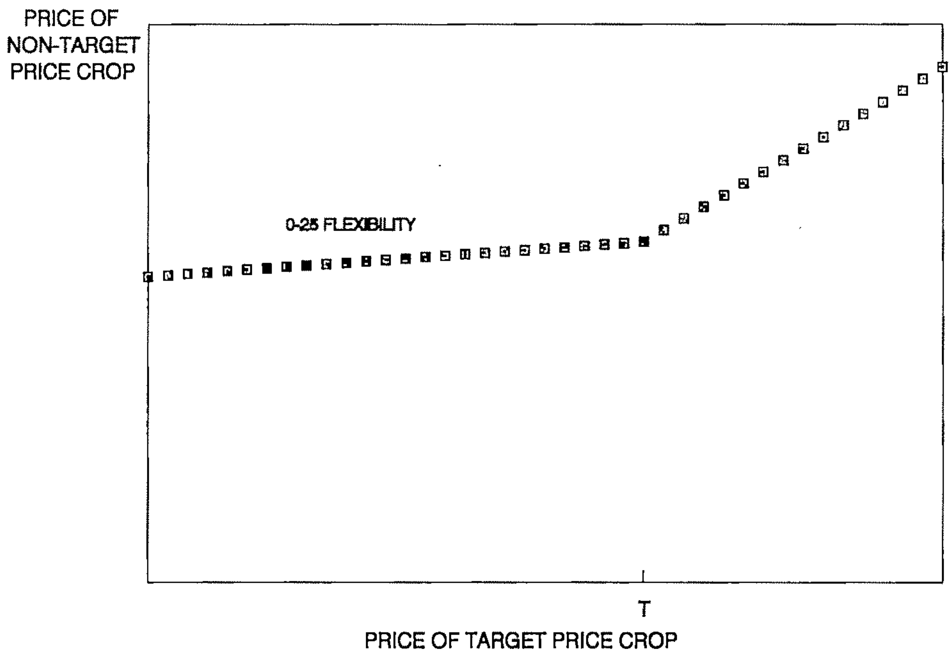


Figure 1. Break-even prices between target price and non-target price crops, flexibility alternatives

price crop, the figure shows the break-even price for the non-target price crop.

The dominant role of deficiency payments in protecting net returns for target price crops is indicated by the nearly horizontal portion of the break-even curve in figure 1, which corresponds to prices for the target price crop below its target price (T). In this range, expected net returns for target price crops are more certain than those for non-target price crops because deficiency payments partially buffer price reductions for target price crops. The slight slope to that portion of the break-even curve reflects an assumption that program yields are below actual yields so that deficiency payments do not apply to some production.[5] At prices above the target price, the break-even curve has a steeper slope, reflecting only market returns.

Now, suppose the alternative crop allowed on permitted acres of a target price crop is another target price crop. Net returns on an acre planted to the original target price crop are shown by equation (2). Net returns for an acre planted to the alternative target price crop would also be expressed by equation (2), with all terms representing the alternative target price crop instead of the original target price crop. Break-even price relationships between the two target price crops can be derived from these net returns expressions. Adding subscripts o or a to each term in equation (2) represents the original and the alternative target price crops, respectively.

Figure 2 illustrates how 0–25 flexibility affects break-even price relationships between two target price crops. As in figure 1, the deficiency payments give a kink in figure 2 where the price for the original target price crop equals its target price (T_o). The result is a nearly horizontal portion of the break-even curve in figure 2 until break-even prices for the alternative target price crop are reduced to its target price (T_a). At this point, a second kink reflects the partly offsetting effects of deficiency payments for the alternative target price crop, with the break-even curve becoming steeper at lower price expectations. When prices of the original target price crop exceed its target price, break-even prices shown for the alternative target price crop are above its target price. The figure has a steeper slope here, reflecting only market returns.

Set-Aside Program Flexibility

For competition between a target price crop and a non-target price crop under set-aside program

[5] For most crops in most regions, actual yields are higher than program yields, particularly since program yields have been frozen. However, if farmers' expectations of actual yields were equal to (less than) program yields, the break-even curve in figure 1 would have a (negative) slope of zero for prices below the target price.

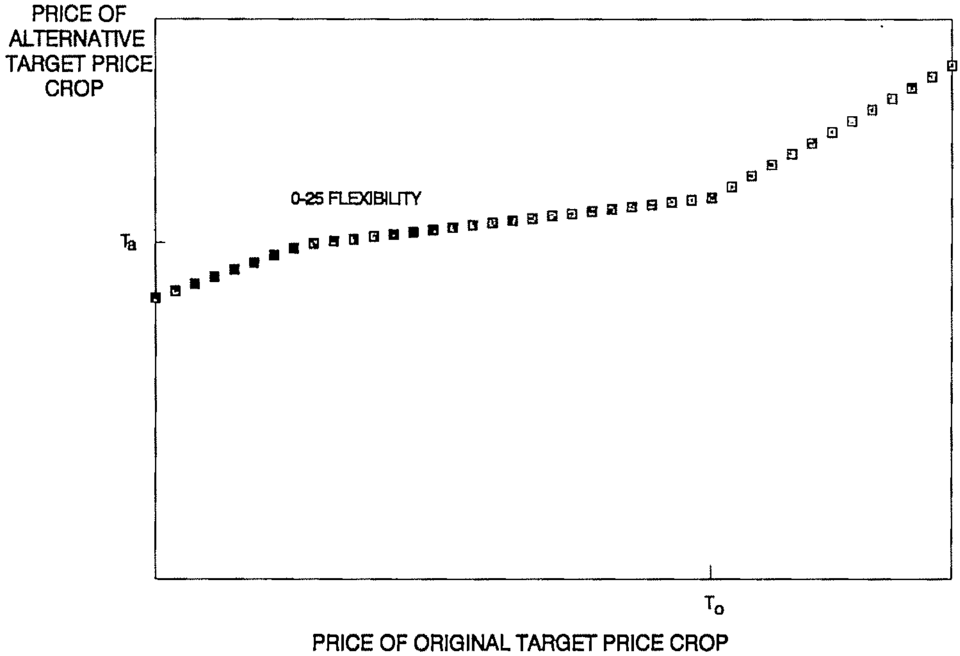


Figure 2. Break-even prices between two target price crops, flexibility alternatives

flexibility, expected net returns to planting an acre with a non-target price crop are shown in equation (1), equaling market revenues minus variable production costs. Expected net returns for the target price crop reflect part of the acre being planted and the remaining part of the acre being idled to comply with ARP provisions. Equation (3) represents these expected net returns, where *ARP* is the acreage reduction program fraction for the target price crop and *VCI* is the per-acre variable cost of maintaining ARP land in a conserving use. Part of the acre (1 − *ARP*) has the same net returns as in equation (2), but the remainder of the acre (*ARP*) has no revenue; it must be maintained in a conserving use to comply with program provisions.

$$(3)\quad NRT = \{PT(YT) + PYT[\max(0, T - PT)] - VCT\}(1 - ARP) - VCI(ARP).$$

Break-even price relationships between a target price crop and a non-target price crop under set-aside program flexibility are derived from equations (1) and (3). These are illustrated by the curve with the plus signs in figure 3. Although the important role of deficiency payments continues for prices of the target price crop below its target price, the inclusion of the *ARP* in the returns to the target price crop lowers the break-even price relationship relative to that for 0–25 flexibility. The decline in the break-even relationship depends on the *ARP* for the target price crop; a higher *ARP* reduces break-even prices more, and a lower *ARP* reduces them less.

The break-even price relationship between two target price crops under set-aside program flexibility is based on expected net returns for each target price crop as expressed in equation (3), adding *o* and *a* subscripts to denote the original and the alternative target price crops, respectively.

The curve with plus signs in figure 4 shows this break-even price relationship. The *ARP* for the original target price crop was assumed to exceed the *ARP* for the alternative target price crop. As a result, the break-even relationship shifts down relative to that for 0–25 flexibility. If the *ARP* for the alternative crop were higher than the *ARP* for the original target price crop, the break-even price relationship would have shifted up from the 0–25 flexibility curve.

For set-aside program flexibility, two kinks again occur in the break-even price relationship between two target price crops. However, with the downward shift in the break-even price curve, the two kinks occur in the opposite order than under 0–25 flexibility. As price expectations for the orginal target price crop decline from above its target price, the first kink occurs where the break-even price for the alternative crop falls to its target price (T_a) and reflects the effects of

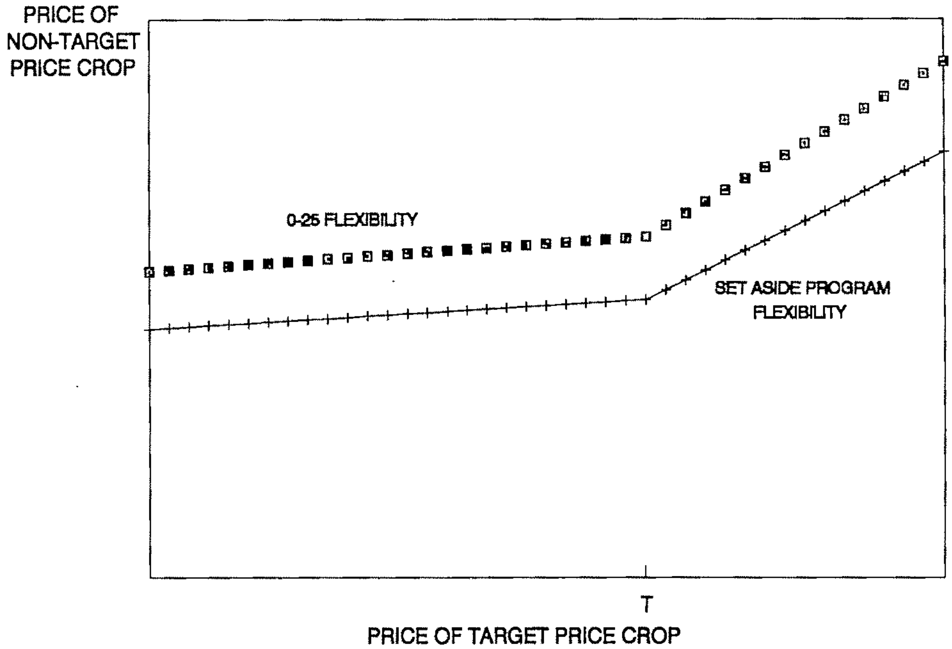


Figure 3. Break-even prices between target price and non-target price crops, flexibility alternatives

deficiency payments for that crop. This results in a relatively steep portion of the break-even relationship until break-even prices for the original target price crop fall to its target price (T_o). At this point, the second kink reflects the effects of deficiency payments of the original target price crop. In this illustration, the effect on break-even prices of deficiency payments for the original target price crop more than offsets the effect of deficiency payments for the alternative crop; thus,

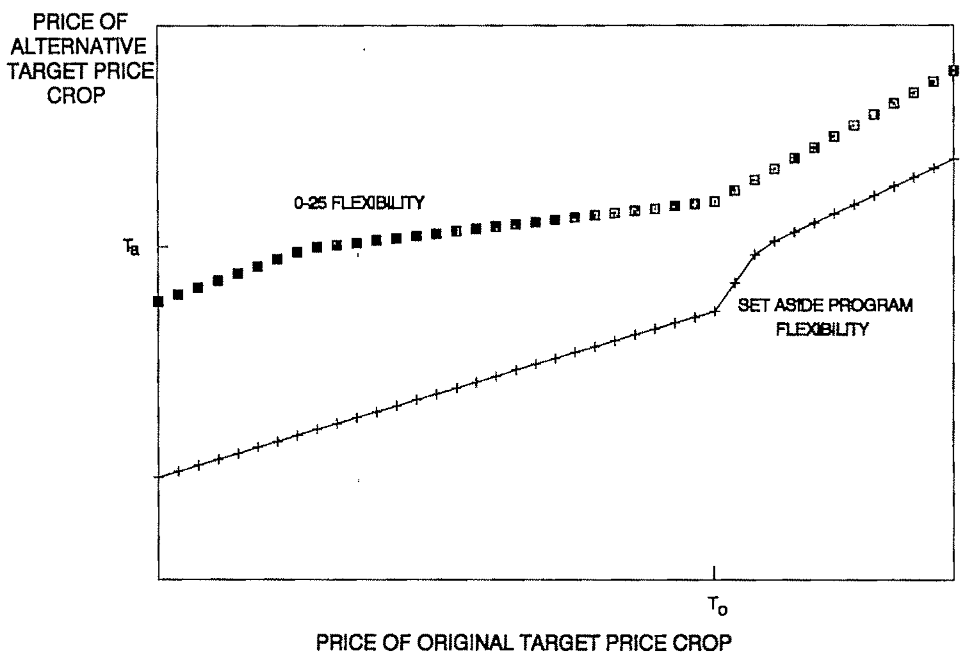


Figure 4. Break-even prices between two target price crops, flexibility alternatives

the curve is flattest where price expectations for the original target price crop are below its target price.

Modified Contract Flexibility

For modified contract flexibility, first consider the option where plantings of the original target price crop in excess of its acreage base would replace plantings of a non-target price crop.[6] Expected net returns for an acre of above-base plantings of the target price crop would be market revenues, minus variable production costs, minus forgone deficiency payments for the target price crop on a matching acre, as shown in equation (4):

$$(4) \quad NRT = PT(YT) - VCT - PYT\,[\max(0, T - PT)].$$

Alternatively, if the farmer does not use the modified contract flexibility, expected net returns for the acre remaining in the non-target price crop would be market revenues minus variable production costs for the non-target price crop, as shown in equation (1).

The break-even price relationship between a target price crop and a non-target price crop under modified contract flexibility can be derived from equations (1) and (4) and is shown in figure 5. Similar to the break-even relationship for 0–25 flexibility shown in figure 1, a kink occurs where the break-even price for the target price crop equals its target price. However, in figure 1, the kink shifts away from the axis of the target price crop because deficiency payments would continue for lower prices if the target price crop were planted. In figure 5, the kink shifts toward the axis for the target price crop because deficiency payments for a matching acre are forgone at lower prices if the target price crop is planted. Thus, lower prices for the alternative crop are sufficient to break even.

For price expectations above the target price, break-even prices between a target price crop and a non-target price crop would be the same as in figure 1. Because there are no deficiency payments at these prices, planting choices would only reflect expected returns from the marketplace.

Net returns and break-even prices under modified contract flexibility are further affected if the above-base plantings of the original target price crop are competing with permitted plant-

[6] Flexibility characteristics are not presented for the option of planting the ARP land up to the full acreage base because general features of those break-even price relationships are similar to those discussed here for the above-base plantings option involving a target price crop and a non-target price crop.

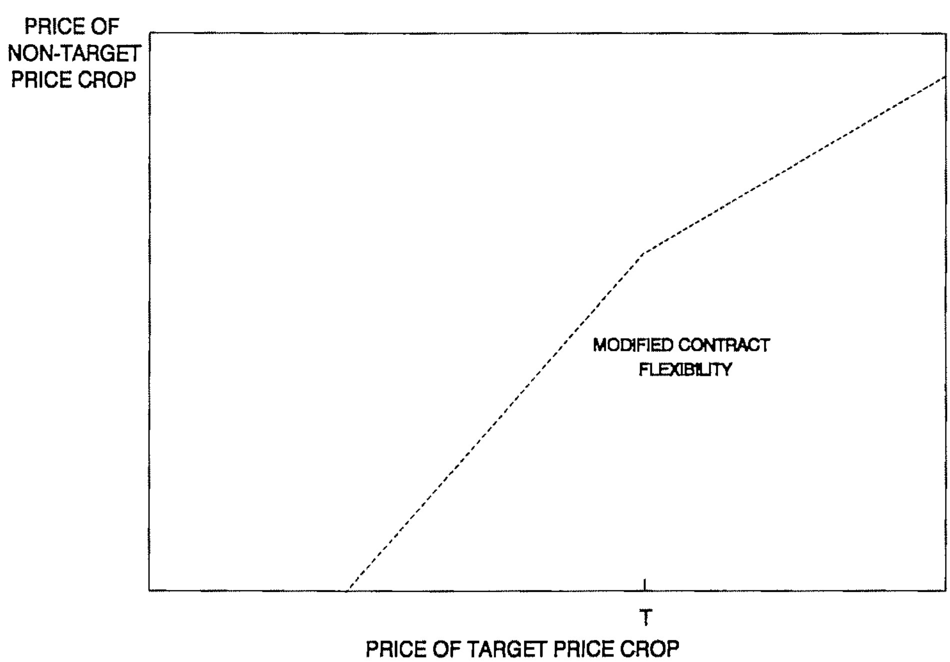


Figure 5. Break-even prices between target price and non-target price crops, flexibility alternatives

ings of another target price crop. Expected net returns for an acre of above-base plantings of the original target price crop are again represented by equation (4).

If the farmer does not use the modified contract flexibility, expected net returns for the acre remaining in the alternative target price crop would be market and farm program revenues minus variable production costs for that crop, as represented earlier in equation (2).

The break-even price relationship between two target price crops under modified contract flexibility can be derived from these net returns equations by adding a subscript *o* to each term in equation (4) and a subscript *a* to each term in equation (2) to denote the original and the alternative target price crops, respectively.

Figure 6 shows the break-even price relationship between two target price crops under this type of flexibility. Similar to the break-even price relationships in figures 2 and 4, there are two kinks in the break-even price curve for modified contract flexibility in figure 6, occurring where the price for each target price crop equals its target price. However, the direction of the shift in the break-even curve at the kink where the price of the original target price crop equals its target price (T_o) is different than before. Here, the shift is toward the horizontal axis because deficiency payments for the original target price crop corresponding to a matching acre are forgone if the original target price crop is planted on the above-base land.

Triple Base Flexibility

Under triple base flexibility, where deficiency payments are eliminated for some acreage regardless of what crop is planted, net returns for non-target price crops are unchanged from equation (1). Net returns for target price crops under this type of flexibility remove the deficiency payment term from equation (2). This leaves net returns for target price crops equal to market receipts minus costs of production, as in equation (5). Thus, planting competition between target price crops and non-target price crops is based only on expected returns from the marketplace.

$$(5) \qquad NRT = PT(YT) - VCT.$$

The "market returns competition" line in figure 7 illustrates the break-even relationship between a target price crop and a non-target price crop under triple base flexibility. The primary difference from previous break-even relationships is the absence of a kink. Because the role

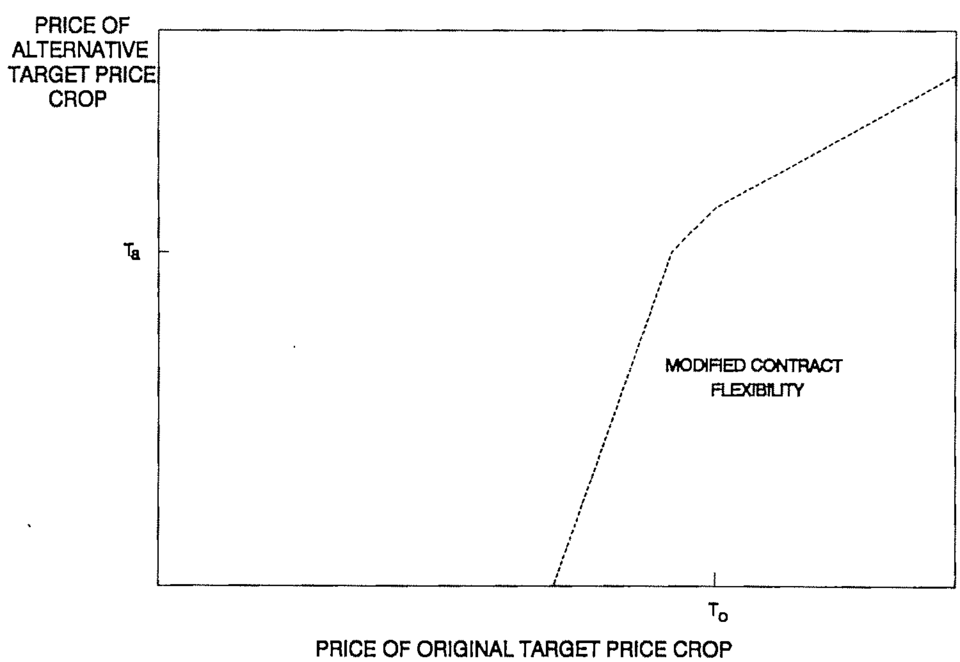


Figure 6. Break-even prices between two target price crops, flexibility alternatives

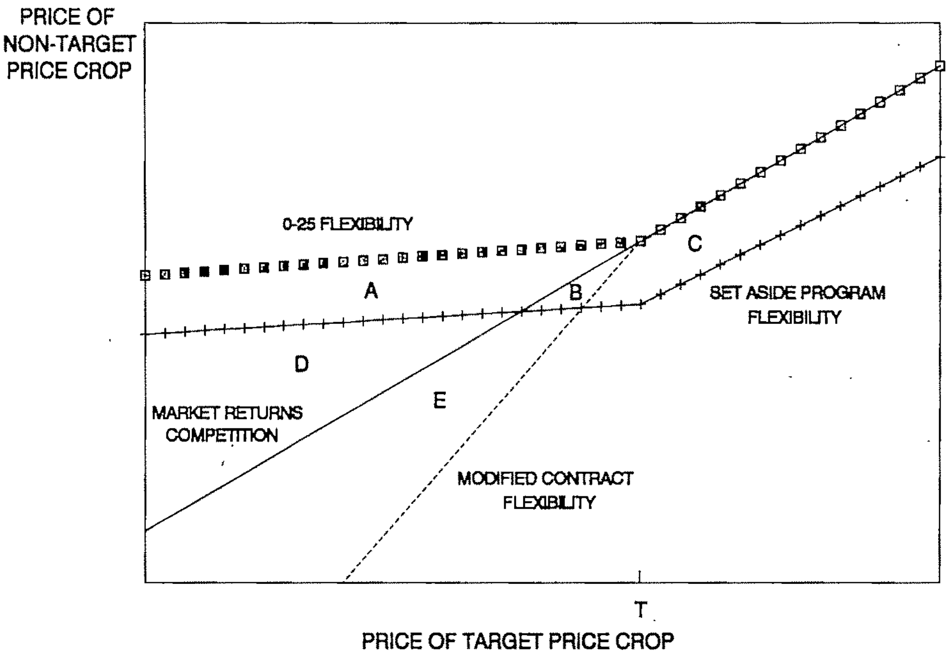


Figure 7. Break-even prices between target price and non-target price crops, flexibility alternatives

of deficiency payments in determining break-even prices is removed, planting decisions are based on market returns when expected prices for the target price crop fall below its target price.

For competition between two target price crops under triple base flexibility, net returns for either the original target price crop or an alternative target price crop are equal to market receipts minus variable costs of production, as in equation (5). Competition between the two target price crops in planting decisions would be based only on expected returns from the marketplace.

The "market returns competition" line in figure 8 illustrates the break-even price relationship between two target price crops under triple base flexibility. As in figure 7, no kinks occur in this break-even line because planting choices are based on market returns for all expected prices.

Administration's Flexibility Proposal

Under flexibility alternatives where government payments for the target price crop continue if an approved alternative crop is planted, returns to planting the target price crop retain the deficiency payment term, as in equation (2). However, returns to an approved alternative crop also would include deficiency payments for the original target price crop. Equation (6) represents expected net returns for planting an approved alternative non-target price crop under this type of flexibility, with the subscript o on components of the deficiency payment term denoting the original target price crop.

$$(6)\quad NRN = PN(YN) - VCN + PYT_o[\max(0, T_o - PT_o)].$$

Because deficiency payments are included in the net returns for both the target price crop [equation (2)] and the non-target price crop [equation (6)], break-even prices would be based only on expected returns from the marketplace, as the deficiency payment terms would be offsetting. Thus, break-even prices between a target price crop and a non-target price crop would be the same as those for the triple base proposal.

As a result, the "market returns competition" line in figure 7 also illustrates the break-even relationship between a target price crop and a non-target price crop under the administration's flexibility proposal. Again, the major differences from break-even relationships for flexibility alternatives where farm program benefits

affect the planting choice is the absence of a kink in the "market returns competition" break-even price line.

For competition between two target price crops under the administration's flexibility proposal, expected net returns for planting the original target price crop would equal market receipts, plus its deficiency payments, minus variable costs of production, as in equation (2). Expected net returns for planting another target price crop would equal market receipts minus variable production costs for the alternative crop plus deficiency payments for the original target price crop, as shown in equation (7) using subscripts a and o, respectively.

$$(7) \quad NRT_a = PT_a(YT_a) - VCT_a + PYT_o[\max(0, T_o - PT_o)].$$

Because deficiency payments for the original target price crop are included in both equations (2) and (7), planting decisions would be based only on expected returns from the marketplace. Thus, break-even prices for the administration's flexibility proposal would be the same as those for triple base flexibility.

Consequently, the "market returns competition" line in figure 8 also illustrates the break-even relationship between two target price crops under the administration's flexibility proposal.

Market Effects

Market effects of flexibility alternatives which allow planting decisions to be based on market returns will depend on year-specific market conditions for different crops. When supply/demand conditions for some crops are tighter than for other crops, their prices will be relatively higher, providing economic incentives for acreage to switch. The greater the relative supply/demand imbalances across commodities, the greater the relative price differences and the greater the incentives for acreage adjustments. Thus, these flexibility alternatives allow market signals to provide the economic incentives for the acreage shifts needed to move toward cross-commodity equilibrium conditions.

Flexibility alternatives that keep deficiency payments in the planting decision would result in distortions in acreage allocations between target price crops and non-target price crops as well as among target price crops in most years. The role of market signals in determining acreage allocations is limited because competition between crops is influenced by farm program benefits.

Figures 7 and 8 illustrate how distortions in acreage allocations can arise under these flexibility alternatives. For price pairs of competing crops above the "market returns competition"

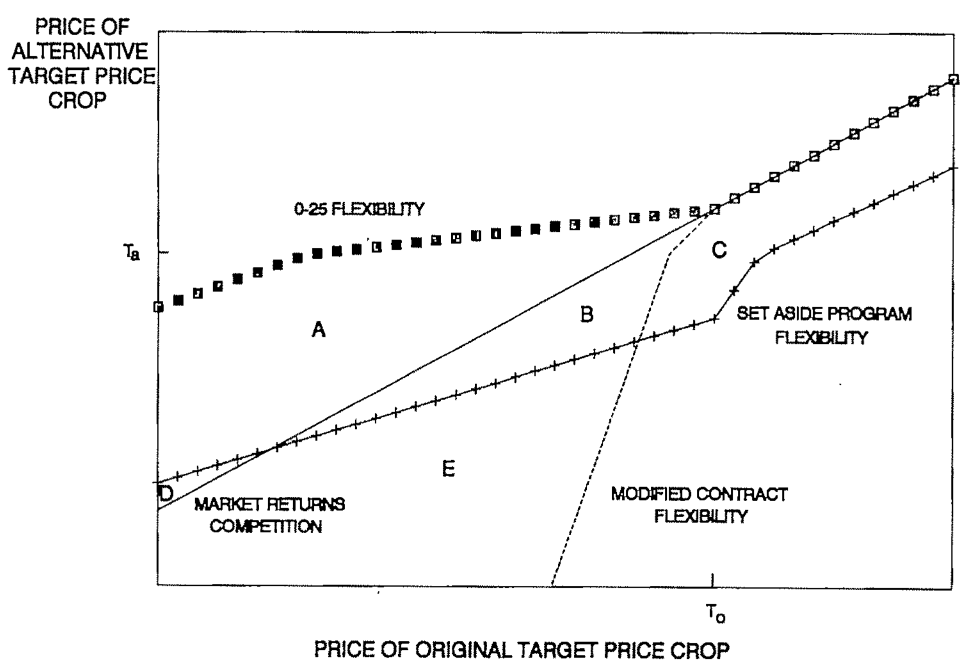


Figure 8. Break-even prices between two target price crops, flexibility alternatives

line, in the regions labeled A and D of each figure, where each such region is defined by the smallest bounds around the letter, market signals favor planting the alternative crop instead of the original target price crop. However, under 0–25 flexibility, price pairs in those regions favor planting the original target price crop. For price pairs below both the 0–25 flexibility break-even curve and the market returns competition line, in regions B and E, plantings of the original target price crop would be favored under 0–25 flexibility and under market returns competition flexibility alternatives. However, 0–25 flexibility would encourage larger acreage shifts than needed for equilibrium.

For set-aside program flexibility, price pairs of competing crops in the regions labeled B and C of figures 7 and 8 would favor planting the alternative crop instead of the original target price crop. However, price pairs in those regions are below the "market returns competition" line, so market signals favor planting the original target price crop. In contrast, for price pairs in region D, market signals favor planting the alternative crop, but plantings of the original target price crop are favored under set-aside program flexibility.

For above-base plantings under modified contract flexibility, the loss of deficiency payments on a matching acre for the original target price crop as well as the competition with other deficiency payments if the alternative crop is also a target price crop effectively limit acreage shifts to periods when expected prices for the original target price crop are near or above its target price. For price pairs of competing crops in figures 7 and 8 in the regions labeled B and E, market signals would favor planting the original target price crop. However, under modified contract flexibility, price pairs in those regions are above the modified contract flexibility break-even curve, thus discouraging above-base plantings of the original target price crop.

Acreage allocation distortions can also result if other program provisions constrain acreage shifts. For example, if acreage adjustments are limited, the speed of adjustment toward equilibrium is slowed even if the flexibility provisions allow acreage shifts to be based on market signals. Further, if there are limitations on alternative crops, acreage may be prevented from shifting to crops with the highest expected net returns.

Conclusions

This article illustrates how planting flexibility alternatives affect farmers' planting choices by showing break-even price relationships derived from an analysis of producer expected net returns. The major factor differentiating among flexibility alternatives is the linkage of farm program benefits to planting choices. If they are linked, program provisions have different effects on break-even prices. The points where kinks occur in break-even price relationships are related to target prices. The direction of shifts in the break-even curves at the kinks is related to the linkage between deficiency payments and the planting choice. The slope of the lines in different ranges of the break-even price relationships reflects how program yields compare to expected yields. If the acreage idled under ARPs is linked to the plantings choice, the break-even curves are related to the relative magnitudes of the ARPs for competing crops. Distortions in acreage allocations can result under these flexibility alternatives because planting choices are influenced by farm program benefits, limiting the role of market signals.

If farm program benefits are separated from the planting choice on some land, then planting decisions would be based on expected market returns for the acreage involved. Deficiency payments may be separated from the planting decision by removing them even if the original target price crop is planted or by continuing them regardless of the crop planted. Acreage allocations are more efficient because planting choices respond directly to price signals from the marketplace. Some distortions may still result if planting flexibility is constrained by limiting the acreage shifts or by restricting the allowable alternative crops.

[Received June 1990; final revision received January 1991.]

References

Glauber, Joe. "Why Aren't Farmers Moving to Soybeans?" *Agr. Outlook*, June 1988, pp. 13–16. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. AO-142.

U.S. Department of Agriculture. *1990 Farm Bill—Proposal of the Administration*. Washington DC, Feb. 1990.

Productivity Growth in U.S. Agriculture Under Dynamic Adjustment

Yir-Hueih Luh and Spiro E. Stefanou

A dynamic measure of productivity growth adjusted for deviations from the long-run equilibrium is established within an adjustment-cost framework. An empirical application to U.S. agriculture is presented which permits identifying the dynamic linkages between technical change and productivity growth in U.S. agriculture. Total factor productivity as dynamically measured grew at 1.50% per annum. The combined effect of scale, quality-adjusted input growth, and long-run disequilibrium input use contributes only 3.44% of the growth, while technical change dominates the growth of total factor productivity.

Key words: costs of adjustments, dynamic duality, productivity growth.

Early efforts in measuring multifactor productivity find that much of the output growth cannot be explained by increases in conventionally defined inputs even after adjusting for improvements in input quality (Solow; Jorgenson and Griliches; Hulten 1975, 1978). Interpretation of this unexplained portion of output growth directly relates total factor productivity growth to shifts in production relations. Focusing on certain market and technical assumptions, Solow shifted attention from investment to technical change as the main engine of growth, leading to use of total factor productivity indices to approximate rates of technical change.

The use of total factor productivity indices is computationally simpler and less demanding than the direct econometric estimation of production technology through production or cost functions. However, a priori restrictions are imposed on the structure of production and markets. Recent developments have relaxed some of the embedded assumptions and decomposed productivity growth into components associated with nonconstant returns, market imperfections, and regulatory effects in addition to technical change (Denny, Fuss, and Waverman; Nadiri and Schankerman; Capalbo; Callan).

The authors are, respectively, an associate professor of economics, National Tsing Hua University, and an associate professor of agricultural economics, Pennsylvania State University.

The assumption of long-run equilibrium implies a constant capacity utilization ratio. Many attempt to adjust the conventional productivity measures for deviation from long-run equilibrium by adjusting the quantity of fixed factors to reflect a variable capacity utilization ratio (Solow; Jorgenson and Griliches; Christensen and Jorgenson; Kendrick; Denison; Norsworth, Harper, and Kunze). Although methodologically different, the adjustments are generally based on ad hoc assumptions. Recent efforts attempt to accommodate temporary equilibrium in measuring total factor productivity growth. Berndt and Fuss employ a different approach by adjusting the price of quasi-fixed factors to reflect their shadow values. This approach, however, does not account for the sluggish adjustment of quasi-fixed factors. The integration of the short- and long-run production decisions within the context of dynamic adjustment provides an alternative approach to accommodate temporary equilibrium in measuring productivity growth.

The dynamic equilibrium model of factor demand has been used to examine the dynamic structure and investment pattern of U.S. agriculture (Vasavada and Chambers 1986, Vasavada and Ball, Howard and Shumway 1988, Taylor and Monson). Agricultural productivity studies assume the observed data reflect static or long-run equilibrium. Assuming sluggish adjustment of some inputs to relative price changes, this study establishes the theoretical methodol-

ogy to adjust measures of productivity growth for deviations from long-run equilibrium within a dynamic optimization framework. By directly relating the total factor productivity measures to characteristics of the production technology, the methodology developed here can isolate nonconstant returns and disequilibrium input use from technical change effects.

The dynamic model of productivity growth is implemented with a theoretically consistent model of dynamic factor demand and output supply response. Annual data for U.S. agriculture over the period 1948–82 are used to estimate the complete system of equations. The dynamic structure of U.S. production agriculture and the importance of the disequilibrium component in measuring and explaining agricultural productivity growth are examined.

Productivity Measurement Under Dynamic Adjustment

Consider the multiple-output production process described by the transformation functions, $F(Y, X, K, \dot{K}, t)$, where Y is the vector of outputs, $Y = (Y_1, \ldots, Y_m)$, X and K are, respectively, the vectors of variable and quasi-fixed inputs, and $\dot{K}$ indicates internal adjustment costs. Time trend t serves as a proxy for technical change. The production technology is characterized by jointness in inputs. Therefore, each input vector in the transformation function defines the total of that input used in production of all outputs.

Within the economically relevant portion of the production surface, the transformation function possesses the following properties:

(*a*) $F(Y, X, K, \dot{K}, t)$ is continuous, twice differentiable, convex and closed set in Y, X, K, and $\dot{K}$ in the nonnegative orthant.

(*b*) $F(Y, X, K, \dot{K}$, t) is strictly increasing in Y and strictly decreasing, convex in X and K.

(*c*) $F(Y, X, K, \dot{K}, t)$ is strictly increasing (decreasing) for increasing (decreasing) $\dot{K}$, and convex in $\dot{K}$.

Assumption (*c*) assures the sluggish adjustment of the quasi-fixed factors. The intertemporal model starts with the competitive firm maximizing the present value of future net cash flows over an infinite horizon. The firm reacts to the competitive market by changing its factor inputs and possibly its capacity utilization. However, the purchase and installation of quasi-fixed inputs involve a cost of adjustment (Lucas, Pindyck). The optimization problem maintains static price expectations and chooses the optimal levels of inputs given exogenous output and factor prices as follows:[1]

$$(1)\quad J(p, w, c, k, t) = \max_{Y,X,I} \int_t^{\infty} e^{-rs}\,[p'Y - w'X - c'K]ds$$

subject to

$$\dot{K} = I - \delta K,\ K(t) = k$$
$$F(Y, X, K, \dot{K}, s) = 0\ t \leq s < \infty.$$

Here, $J(p, w, c, k, t)$ is the value function depending on the quasi-fixed factor stocks at the beginning of the period, k, the price of output, p, the vector of variable input prices, w, and the rental price for the quasi-fixed factor stocks, c, and time. The constant discount and depreciation rates are denoted by r and δ, respectively, and I is the gross investment of the quasi-fixed inputs.

Based on intertemporal optimization, the firm operates in the short run but plans ahead to select a future short-run production situation (Stefanou). The value function $J(p, w, c, k, t)$ represents the long-run profit function for the competitive firm.

The dual approach to defining productivity growth considers the proportional rate of output growth in terms of observed prices and quantities. The explicit derivation of productivity growth under dynamic adjustment is presented in the appendix. The measured output growth in productivity contains three components: technical change, scale, and disequilibrium components, and it has the form

$$(2)\quad \hat{Y} = \frac{TSC}{TR}(\hat{F}_v + \hat{F}_{q_1} + \hat{F}_{q_2} + \hat{F}_{ss}) + \hat{A}.$$

The ratio of total shadow costs (TSC) to total revenues (TR) is the inverse of the sum of the cost elasticities for each output in an intertemporal cost minimization problem evaluated at the profit maximization position (Luh). The multiple output measure of the proportional growth in output is $\hat{Y}$; $\hat{F}_v$ represents the proportional rate of growth in variable input use; $\hat{F}_{q_1}$ and $\hat{F}_{q_2}$ are disequilibrium components. The first measures

[1] Price expectations are static in the sense that relative prices observed in each base period are assumed to persist indefinitely. As the base period changes, expectations are altered and previous decisions are no longer optimal. Only that part of the decision corresponding to each base period is actually implemented. A growth process for prices can be easily accommodated. (See Epstein and Denny for the deterministic case.)

the proportional growth in net physical investment, while the second captures the proportional changes in the endogenously determined marginal values of quasi-fixed factor stocks. Component $\hat{F}_{s}$ reflects the proportional growth in quasi-fixed factor levels at long-run equilibrium, and $\hat{A}$ represents the shift in the multiple-output technology resulting from technical progress.

Total factor productivity growth, $T\hat{F}P$, is the residual growth in outputs not explained by the growth in input use, input stock, and the valuation of the input stock:

$$(3)\qquad T\hat{F}P = \hat{Y} - [\hat{F}_{v} + \hat{F}_{q_1} + \hat{F}_{q_2} + \hat{F}_{s}].$$

From equation (2), total factor productivity growth is decomposed as

$$(4)\qquad T\hat{F}P = \hat{A} + \left(\frac{TSC}{TR} - 1\right)[\hat{F}_{v} + \hat{F}_{q_1} + \hat{F}_{q_2} + \hat{F}_{s}].$$

Dynamic Productivity Growth in U.S. Agriculture

The official statistics published by the U.S. Department of Agriculture have been used to measure productivity for the aggregate agriculture industry. Recently, both Ball and Capalbo report revised productivity indices motivated by improvements for constructing certain inputs and in providing an indexing procedure which does not restrict the structure of production. Results of both studies indicate that the growth of aggregate agriculture output results primarily from technical change.

Capalbo also reports alternative measures of total factor productivity growth based on econometric estimation of the production technology. Comparison to the conventional Tornqvist-Theil indices indicates underestimation of the rate of technical change when constant returns to scale is assumed. Although the static measure allows for nonconstant scale effects, the maintained assumption of long-run equilibrium implies instantaneous and full adjustment of all inputs to relative price changes. The gradual adjustment of capital and agricultural labor are well documented in U.S. production agriculture (Vasavada and Chambers 1986, Vasavada and Ball, Taylor and Monson). Consequently, deviations from long-run equilibrium are likely when these factors experience slow adjustment.

Data

Annual data for aggregate U.S. agriculture over the period 1948–82 are taken from Capalbo, Vo, and Wade. The U.S. agriculture data base is constructed using the Tornqvist approximation to the Divisia quantity indices, and corresponding implicit prices are calculated using the total expenditure information. The data base consists of six output groups (small grains, coarse grains, field crops, fruits, vegetables, and animal products) and five input groups (labor, land, intermediate and material inputs, structure, and other capital). Further aggregation is required to gain degrees of freedom. The first five output groups are aggregated into a single crop output. The implicit price for crop output is calculated using the translog quantity indices and the implicit prices for the first five output groups. Land, capital, and other capital (including durable equipment, livestock, and livestock inventory) are further aggregated into a single capital input applying the same aggregation rule.

The aggregation rule used in the empirical analysis to make the data conformable with the specified model is the Tornqvist discrete approximation to the Divisia indexing procedure. The quantity index Q_0 has the following form:

$$Q_o = \ln\frac{q_t}{q_{t-1}} = \frac{1}{2}\sum_{i=1}^{N}[\omega_{i,t} + \omega_{i,t-1}]\ln\frac{\chi_{i,t}}{\chi_{i,t-1}},$$

where $\ln(q_t)$ is the aggregate translog quantity index, $\omega_{i,t}$ is the revenue (cost) share of the ith output (input) in the aggregate group, and $\chi_{i,t}$ denotes the quantity of the ith elements being aggregated.

Model Specification

The dynamic duality between the value function and underlying production technology permits the derivation of a system of equations consistent with dynamic optimization behavior. Closed-form expressions for the unknown equations cannot be obtained without appropriate specification of the value function. Given the duration of postwar data series at the aggregate national level, and for parsimony, most studies of aggregate investment behavior adopt a second-order expansion of the value function (e.g., in agriculture see Vasavada and Chambers 1982, 1986; Lopez; Vasavada and Ball; Howard and Shumway 1988, 1989; Taylor and Monson). Although these functional forms are not truly flex-

ible as required by the intertemporal optimization setting, the specifications in the cited work are consistent with the flexible accelerator model with J_k linear in c.

In the present analysis, the value function is specified as the modified generalized Leontief function used by Vasavada and Chambers (1982) and Howard and Shumway (1988). In addition to the regularity properties of the value function, two additional assumptions are modeled to conform with the restrictions imposed by observed data.[2] The first assumption involves the necessary and sufficient conditions for applying a firm-level theory to aggregate data. While the adjustment-cost model is a model of firm behavior, it has been extensively used at the aggregate level. Consistent aggregation requires that the aggregate wealth function is linear in the aggregate capital stock, which in turn requires that the second derivative of the value function with respect to the initial capital stock equals zero, i.e., $J_{kk} = 0$ (Blackorby and Schworm).

The second assumption concerns the discrete nature of the observed data. Net investment, $\dot{K}$, is constructed in terms of the instantaneous changes, while economic data generally come in a discrete time form. Thus, an approximated discrete measure of the net investment must be developed. In most studies involving the specification of $\dot{K}$, the approximation for net investment is based on the difference between the current and lagged capital stock. Net investment, $\dot{K}(\tau)$, is discretely approximated by $K_\tau - K_{\tau-1}$.

Let p represent the (2×1) vector of output prices, subscript 1 denotes crop output, and 2 denotes animal output. The (2×1) vector of stock of quasi-fixed inputs is K, and k_1 is the stock of capital input; k_2 is that of labor. The (2×1) vector, c, is the corresponding rental prices, X denotes the quantity of the only variable input, intermediate input, and w is its corresponding price. Also, let the time trend, t, represent disembodied technological change. The modified generalized Leontief value function with two outputs (Y_1, Y_2), one variable input (X_1), and two quasi-fixed inputs (k_1, k_2) is of the following form:

$$(5)\quad J(p, w, c, k, t) = [p'w]\begin{bmatrix} A_{pk} \\ A_{wk} \end{bmatrix} k + c'BK$$

$$+ [p^{1/2'}w^{1/2}]\begin{bmatrix} A_{pc} \\ A_{wc} \end{bmatrix} c^{1/2} + c^{1/2'}Fc^{1/2}$$

$$+ [p^{1/2'}w^{1/2}]\begin{bmatrix} A_{pp} & A_{pw} \\ A_{wp} & A_{ww} \end{bmatrix}\begin{bmatrix} p^{1/2} \\ w^{1/2} \end{bmatrix}$$

$$+ [A_p A_w A_c]\begin{bmatrix} p \\ w \\ c \end{bmatrix} t,$$

where F and A_{pp} are symmetric and

$$\begin{aligned} B^{-1} &= [A_{ij}]_{2\times 2} & A_{pp} &= [H_{ij}]_{2\times 2} \\ A_{wk} &= [D_j]_{1\times 2} & A_{pw} &= [I_i]_{2\times 1} \\ A_{pc} &= [E_{ij}]_{2\times 2} & A_w &= [M_{21}]_{1\times 1} \\ A_{pk} &= [B_{ij}]_{2\times 2} & A_{ww} &= [J_{pp}]_{1\times 1} \\ A_{wc} &= [F_j]_{1\times 2} & A_p &= [M_{1i}]_{1\times 2} \\ F &= [G_{ij}]_{2\times 2} & A_c &= [M_{3i}]_{1\times 2}. \end{aligned}$$

Applying the envelope theorem to the value function yields the dynamic factor demand, variable factor demands and output supply system (Epstein)

(6)

$$\dot{K}_i^* = (r + A_{ii})k_i + A_{i\gamma}k_\gamma + \sum_j^2 A_{ij}M_{3j}(rt - 1)$$

$$+ \frac{r}{2}\sum_j^2 A_{ij}\left[\sum_p^2 E_{pj}\left(\frac{p_p}{c_j}\right)^{1/2} + F_j\left(\frac{w}{c_j}\right)^{1/2}\right.$$

$$\left. + 2\sum_\alpha^2 G_{\alpha j}\left(\frac{c_\alpha}{c_j}\right)^{1/2}\right], \text{ for } i \neq \gamma.$$

$$(7)\quad X^* = -\frac{r}{2}\left[\sum_j^2 F_j\left(\frac{c_j}{w}\right)^{1/2}\right.$$

$$\left. + 2\sum_\alpha^2 I_\alpha\left(\frac{p_\alpha}{w}\right)^{1/2} + 2J_{pp}\right]$$

$$+ \sum_j^2 D_j(\dot{K}_j^* - rk_j) + M_{2j}(1 - rt)$$

(8)

$$Y_i^* = \frac{r}{2}\left[\sum_j^2 E_{ij}\left(\frac{c_j}{p_i}\right)^{1/2} + 2\sum_j^2 H_{ij}\left(\frac{p_j}{p_i}\right)^{1/2}\right.$$

$$\left. + 2I_i\left(\frac{w}{p_i}\right)^{1/2}\right] + \sum_j^2 B_{ij}(rk_j - \dot{K}_j^*)$$

$$+ M_{1i}(rt - 1).$$

The second-order derivative of the value function with respect to k and c, J_{kc}, is independent

[2] The value function is twice continuously differentiable, concave in quasi-fixed inputs, and convex in prices.

of either the output or input prices. Consequently, the optimal net investment demand equations yield the multivariate flexible accelerator model. In the multivariate flexible accelerator model, optimal investment demands are fixed proportions of the divergence between current quasi-fixed factor stocks and the desired levels of the quasi-fixed factors,

$$\dot{K}^* = (r + A)(K - \bar{K}^*), \tag{9}$$

where $\bar{K}^*$ is the long-run equilibrium or desired levels of the ith quasi-fixed factor. The long-run, quasi-fixed factor equations can be found by setting $\dot{K}^* = 0$, yielding

$$\bar{K}^* = -\begin{bmatrix} r + A_{11} & A_{12} \\ A_{21} & r + A_{22} \end{bmatrix}^{-1} \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} x \begin{bmatrix} M_{31}(rt - 1) + \frac{r}{2}\left(\sum_{\rho}^{2} E_{\rho 1}\left(\frac{p_\rho}{c_1}\right)^{1/2} + F_1\left(\frac{w}{c_1}\right)^{1/2} + 2\sum_{\alpha}^{2} G_{\alpha 1}\left(\frac{c_\alpha}{c_1}\right)^{1/2}\right) \\ M_{32}(rt - 1) + \frac{r}{2}\left(\sum_{\rho}^{2} E_{\rho 2}\left(\frac{p_\rho}{c_2}\right)^{1/2} + F_2\left(\frac{w}{c_2}\right)^{1/2} + 2\sum_{\alpha}^{2} G_{\alpha 2}\left(\frac{c_\alpha}{c_2}\right)^{1/2}\right) \end{bmatrix}.$$

Measuring the Components of Dynamic Productivity Growth

A constant discount rate of 6% is assumed, and a linear disturbance vector with mean vector zero and variance-covariance matrix Σ is appended to the system of equations (6), (7), and (8). Joint estimation of the complete system provides parameter estimates of the value function represented by equation (5). The estimation procedure is the iterated seemingly unrelated regression method (ITSUR) implemented in the SAS program. Asymptotically efficient parameter estimates along with the corresponding approximate standard errors of equation (5) are reported in table 1. Imposing independent adjustment yields a chi-square test statistic of 2.34 with 2 degrees of freedom (Gallant and Jorgenson). The assumption of independent adjustment is maintained throughout the analysis.

The estimated adjustment rates for the reduced model (also see table 1) indicate capital and labor both adjust sluggishly toward their desired levels in response to relative price changes. The adjustment rate for physical capital is -0.15, implying nearly seven years to adjust to the long-run equilibrium level. With an estimated adjustment rate of -0.11, labor takes nearly nine years to adjust to its long-run equilibrium level.[3] Other analyses for U.S. agriculture (Vasavada and Chambers 1986, Vasavada and Ball, Howard and Shumway 1988, Taylor and Monson) report adjustment rates for physical capital and labor, respectively, ranging from -0.09 to -0.55 and from -0.07 to -0.4. The present study predicts similar long lags in the adjustment of both capital and labor compared to Vasavada and Chambers (1986).

The proportional growth of output over time and the scale-related components constituting this growth are given in table 2. Over the 1950–82 time span, aggregate agricultural output grew at an average annual rate of 1.45%. Estimates of the scale elasticities are consistent with Capalbo's estimates (0.788 as an average over the period) and reflect the decreasing returns-to-scale characteristics of the post-World War II U.S. agriculture structure. However, the results indicate that returns to scale are overestimated when long-run equilibrium is maintained.

The scale-related components constituting the growth in agricultural output involve the growth in variable factors, $\hat{F}_v$, the growth in the quasi-fixed factor levels at the long-run equilibrium, $\hat{F}_{u}$, and the growth in net physical investment, $\hat{F}_{q_1}$.[4] Variable inputs and net physical investment grew at an average annual rate of 0.67% and 0.53%, respectively. The average annual growth rate for the long-run equilibrium quasi-fixed factor levels is negative 1.24%.

Capalbo indicates that the Divisia input index in the agricultural data base reflects adjustments

[3] This adjustment rate represents an aggregate labor response; it is not a reliable measure for adjustment solely in owner/operator. Because labor is an aggregation of family and hired sources, the significant degree of sluggish adjustment of labor does not allow one to distinguish between adjustment in family and hired labor.

[4] The postulated form of the value function restricts the change of the endogenously determined marginal valuation of the quasi-fixed factor stocks over time, $dJ_k/dt = 0$. Therefore, the second disequilibrium components, $\hat{F}_{q_2}$, involving the proportional changes in J_k vanish.

Table 1. Coefficient Estimates of the Full and Reduced Models

Coefficient	Full Model Estimate	Full Model Standard Error	Reduced Model Estimate	Reduced Model Standard Error
$A11$	−0.18765	0.10807	−0.21299	0.11146
$A22$	−0.19175	0.03293	−0.17037	0.02912
$A12$	0.00734	0.01557		
$A21$	0.29361	0.19538		
$E11$	14.93487	6.75410	7.56604	5.94062
$E12$	−52.06728	14.90525	−55.00391	10.89442
$E21$	25.27252	5.61419	26.42286	5.90569
$E22$	29.79430	14.81450	21.64626	13.24681
$F1$	17.71703	3.54777	18.21369	3.76333
$F2$	14.80112	8.38289	14.05383	9.20912
$G11$	−54.63073	12.41109	−57.18595	10.04098
$G12$	−14.12914	9.03879	−8.89500	10.27608
$G22$	39.26210	25.86006	25.58272	17.51946
$M11$	0.71299	0.13097	0.77721	0.11831
$M12$	0.17433	0.10955	0.16527	0.09956
$M21$	−0.92654	0.08217	−0.95244	0.08478
$M31$	0.47942	0.33966	0.49661	0.18503
$M32$	0.29978	0.96730	−0.31243	0.78058
$I1$	2.17565	2.77486	2.74949	2.81550
$I2$	−27.46902	3.72053	−27.83852	3.79070
$J\rho\rho$	−23.91136	5.63361	−24.76016	5.52585
$D1$	0.42414	0.54522	0.71609	0.52472
$D2$	−0.04909	0.09229	−0.08408	0.08690
$H11$	−7.88656	13.22661	−20.31155	15.23774
$H12$	13.12113	3.31773	15.35310	2.53602
$H22$	52.93528	8.22547	54.85810	8.81484
$B11$	2.19578	1.52271	2.62688	1.57805
$B12$	0.39172	0.14561	0.56260	0.13137
$B21$	−1.78263	1.18676	−1.64844	1.05575
$B22$	−0.02569	0.10098	−0.09476	0.08882

for changes in composition and education of the labor force, the use of service prices for capital and land, and adjustments to the pesticides and fertilizer inputs (Capalbo, p. 61). Therefore, the bracketed term at the right-hand-side of equation (4) represents the combined effect of scale, quality-adjusted growth in variable and quasi-fixed inputs, and the disequilibrium input use. The major implication of table 2 is that 98.5% of the growth of aggregate agriculture output over the 1950–82 period is a result of technical change [i.e., $\hat{Y} - TSC/TR(\hat{F}_v + \hat{F}_{q_1} + \hat{F}_{ss})$]. The rest is attributed to the combined effects of scale, quality-adjusted input growth, and disequilibrium. Although Capalbo and Ball reach similar conclusions that aggregate output growth results primarily from technical change, the dynamic adjustment model indicates an underestimate of the true contribution of technical change in output growth when long-run equilibrium is assumed.

The long-run measures of total factor productivity over the period 1950–82 are presented in table 3. Compared with the productivity index reported in Capalbo and in Ball (also see table 3), the dynamic measure exceeds the conven-

Table 2. Proportional Growth of Output Over Time and the Scale-Related Components (Average Values)

Years	$\hat{Y}$	$\frac{TSC}{TR}$	$\hat{F}_v$	$\hat{F}_{ss}$	$\hat{F}_{q1}$
1950–59	0.00903	0.47093	0.01049	−0.03309	0.01902
1960–69	0.00947	0.56348	0.00809	−0.01081	−0.00004
1970–82	0.02266	0.75210	0.00261	0.00236	−.00128
1950–82	0.01453	0.60974	0.00666	−0.01237	.00525

Table 3. Static and Dynamic Measures of Total Factor Productivity Indices for U.S. Agriculture, 1950–82

Year	Ball[a]	Capalbo[b]	Dynamic[c]
1950	58.10	67.00	73.31
1951	61.30	68.87	83.23
1952	61.30	71.89	84.96
1953	62.60	74.33	85.58
1954	64.10	74.21	83.75
1955	66.10	73.51	85.79
1956	68.90	79.11	72.21
1957	69.80	77.19	107.58
1958	71.40	78.62	92.66
1959	73.60	75.84	85.70
1960	75.70	77.99	78.75
1961	76.60	78.64	80.80
1962	76.80	80.17	81.85
1963	81.10	81.54	87.58
1964	81.90	83.41	89.81
1965	85.80	82.62	84.38
1966	83.10	83.45	90.79
1967	86.00	85.44	88.22
1968	85.30	85.63	85.04
1969	87.80	86.55	88.47
1970	85.50	84.36	79.29
1971	91.40	88.70	90.74
1972	91.90	89.69	88.44
1973	92.50	91.15	89.30
1974	91.90	94.40	93.90
1975	98.30	96.32	94.98
1976	94.70	96.31	97.26
1977	100.00	100.00	100.00
1978	98.70	97.29	92.52
1979	104.40	102.50	101.02
1980		102.31	100.76
1981		109.63	107.98
1982		110.71	113.14

[a] The Tornqvist-Theil total factor productivity indices reported in Ball.
[b] The Tornqvist-Theil total factor productivity indices reported in Capalbo.
[c] The dynamic measures of total factor productivity.

tional Tornqvist-Theil measure over the period 1950–70. However, during the 1960s and early 1980s, the dynamic model measures a smaller total factor productivity than is generated by the conventional indexing procedure.[5]

Given the common data source, it is more meaningful to compare the dynamic total factor productivity growth results to Capalbo's study. Excess capacity occurs when the dynamic growth exceeds the static total factor productivity growth, and full capacity utilization occurs when the two measures are equal. When the static total factor productivity growth exceeds the dynamic measure, increased variable factor use rather than quasi-fixed factor expansion accounts for the output levels exceeding those associated with the efficient quasi-fixed factor stock utilization. While the productivity growth estimates are point estimates of random variables, the pattern of differences between the dynamic and static measures is fairly robust. The period 1950–59 is characterized by relatively large, positive differences (over 11% a year on average) suggesting considerable excess capacity. The period 1960–69 is characterized by relatively small, positive differences (approximately 3% a year on average), suggesting full capacity utilization in production agriculture during this decade. The period 1970–82 is characterized by relatively small, negative differences (approximately 1% a year on average). The rapid escalation of world food prices in the early to mid-1970s encouraged producers to produce beyond full capacity while capital capacity was adjusting.

The key to the dynamic measure of total factor productivity is the rationalization of nonconstant-returns-to-scale technology and the fact that some of the inputs may not be applied at their long-run equilibrium levels. Recognizing the decreasing returns-to-scale characteristic of aggregate agriculture production, the parametrically measured technical change reported by Capalbo indicates an underestimation of the rate of technical change. By further relaxing the assumption of long-run equilibrium, both the conventional Tornqvist-Theil productivity indices and static parametric measures overstate the rate of advancement in technology for U.S. agriculture over the 1950–82 period. The productivity residual as dynamically measured is 17.22% smaller than the conventionally measured total factor productivity growth reported in Ball, and 7.14% and 16.75% smaller than the conventionally measured growth and the parametrically measured technical change reported in Capalbo, respectively.

Table 4 presents the quantitative decomposition of the long-run total factor productivity growth measure consistent with equation (4). Total factor productivity as dynamically measured grew at 1.50% per annum. The combined effect of scale, quality-adjusted input growth, and long-run disequilibrium input use contributes only 3.44% of the growth, while technical change dominates the growth of total factor pro-

[5] During the period 1956–58, the dynamic total factor productivity growth estimates experience large discrete jumps. The largest change, 35% in 1957, is accounted for by 22% and 13% growth in the scale and technical change components, respectively. The large jumps in this short time span apparently are artifacts of the estimation and the data. Such dramatic changes do not occur over any other periods. The results presented here are dependent upon econometric estimates and are subject to random errors for any given point estimate.

Table 4. Components of Dynamic Total Factor Productivity Growth (Average Values)

Years	$T\hat{F}P$	Scale[a]	Technical Change
1950–59	0.01261	0.00310	0.00951
1960–69	0.01222	0.00159	0.01063
1970–82	0.01898	−0.00229	0.02128
1950–82	0.01500	0.00052	0.01449

[a] This component is calculated using the expression

$$\left(\frac{TSC}{TR} - 1\right)(\hat{F}_v + \hat{F}_{q1} + \hat{F}_{x}).$$

ductivity. The importance of technical change is not surprising. However, the results must be cautiously interpreted by recognizing the shortcomings for residually determining the rate of technical change. Included are errors resulting from the estimation and given the high level of aggregation for the capital variable.

Concluding Comments

This study develops measures of productivity growth applicable to a more general structure of production than have been previously considered. The dynamic adjustment model provides a basis for explaining agricultural investment patterns and some of the adjustment problems experienced by the agricultural production sector.

Vasavada and Chambers (1986) argue that sluggish input adjustments represent a form of asset fixity. In addition, the traditional farm problem of low resource returns can be addressed within the adjustment-cost framework because additional investment involves a positive adjustment cost. The empirical results of this study indicates that both capital and agricultural labor adjust sluggishly to their long-run equilibrium levels. These results in turn suggest that asset fixity is important in U.S. production agriculture.

This study further indicates that the adjustment for departure from long-run equilibrium makes an important difference in the measurement of productivity growth. For these studies decomposing productivity growth by regressing total factor productivity indices on research, extension, and other variables, the contribution from public research and extension to productivity growth is misrepresented when some of the inputs are not applied at their long-run equilibrium levels.

[Received April 1990; final revision received November 1990.]

References

Ball, V. E. "Output, Input, and Productivity Measurement in U.S. Agriculture, 1948–79." *Amer. J. Agr. Econ.* 67(1985):475–86.

Berndt, E. R., and M. A. Fuss. "Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium." *J. Econometrics* 33(1986):7–29.

Blackorby, C., and W. Schworm. "Aggregate Investment and Consistent Intertemporal Technologies." *Rev. Econ. Stud.* 49(1982):595–614.

Callan, S. J. "Productivity, Scale Economics, and Technical Change: Reconsidered." *S. Econ. J.* 54(1988):715–24.

Capalbo, S. M. "Measuring the Components of Aggregate Productivity Growth in U.S. Agriculture." *West. J. Agr. Econ.* 13(1988):53–62.

Capalbo, S. M., T. T. Vo., and J. C. Wade. "An Econometric Data Base for Measuring Agricultural Productivity and Characterizing the Structure of U.S. Agriculture." Washington DC: National Center for Food and Agricultural Policy Disc. Pap. Ser. No. RB85-01, 1985.

Christensen, L. R., and D. W. Jorgenson. "U.S. Real Product and Real Factor Input, 1929–1967." *Rev. Income and Wealth* 16(1970):19–50.

Denison, E. F. "Accounting for Slow Economic Growth: The United States in the 1970's." Washington DC: The Brookings Institution, 1979.

Denny, M., M. Fuss, and L. Waverman. "The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications." *Productivity Measurement in Regulated Industries*, ed. T. G. Cowing and R. E. Stevenson, chap. 8. Orlando FL: Academic Press, 1981.

Epstein, L. G. "Duality Theory and Functional Forms for Dynamic Factor Demands." *Rev. Econ. Stud.* 48(1981):81–95.

Epstein, L. G., and M. G. S. Denny. "The Multivariate Flexible Accelerator Model: Its Empirical Restrictions and an Application to U.S. Manufacturing." *Econometrica* 51(1983):647–74.

Gallant, A. R., and D. W. Jorgenson. "Statistical Inference for a System of Simultaneous, Nonlinear, Implicit Equations in the Context of Instrumental Variable Estimation." *J. Econometrics* 4(1979):275–302.

Howard, W. H., and C. R. Shumway. "Dynamic Adjustment in the U.S. Dairy Industry." *Amer. J. Agr. Econ.* 70(1988):837–47.

——. "Nonrobustness of Dynamic Dual Models of the U.S. Dairy Industry." *Northeast. J. Agr. and Resour. Econ.* 18(1989):18–25.

Hulten, C. R. "Technical Change and the Reproducibility

of Capital." *Amer. Econ. Rev.* 65(1975):956–65.
——. "Growth Accounting with Intermediate Inputs." *Rev. Econ. Stud.* 45(1978):511–18.
Jorgenson, D. W., and Z. Griliches. "The Explanation of Productivity Growth." *Rev. Econ. Stud.* 34(1967):249–83.
Kendrick, J. W. "Postwar Productivity Trends in the United States, 1948–1969." New York: Columbia University Press for the National Bureau of Economic Research, 1973.
Lopez, R. E. "The Structure of Production and the Derived Demand for Inputs in Canadian Agriculture." *Amer. J. Agr. Econ.* 62(1980):38–45.
Lucas, R. E. "Adjustment Costs and the Theory of Supply." *J. Polit. Econ.* 75(1967):321–34.
Luh, Y.-H. "Dynamic Linkages, Learning, and Productivity Growth in U.S. Agriculture." Ph.D. thesis, Pennsylvania State University, 1990.
Nadiri, M. I., and M. A. Schankerman. "The Structure of Production, Technological Change, and the Rate of Growth of Total Factor Productivity in the U.S. Bell System." *Productivity Measurement in Regulated Industries*, ed. T. G. Cowing and R. E. Stevenson, chap. 9. New York: Academic Press, 1981.
Norsworth, J. R., M. J. Harper, and K. Kunze. "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors." *Brookings Pap. on Econ. Activity* 2(1979):387–421.
Pindyck, R. "Adjustment Costs, Uncertainty, and the Behavior of the Firm." *Amer. Econ. Rev.* 72(1982):415–27.
Solow, R. M. "Technical Change and the Aggregate Production Function." *Rev. Econ. and Statist.* 39(1957):312–20.
Stefanou, S. E. "Returns to Scale in the Long Run: The Dynamic Theory of Cost." *S. Econ. J.* 55(1989):570–79.
Taylor, Timothy T., and Michael Monson. "Dynamic Factor Demands and the Effects of Energy Price Shocks." *S. J. Agr. Econ.* 17(1985):1–9.
Vasavada, U., and V. E. Ball. "A Dynamic Adjustment Model for U.S. Agriculture: 1948–79." *Agr. Econ.* 2(1988):123–37.
Vasavada, U., and R. G. Chambers. "Investment in U.S. Agriculture." *Amer. J. Agr. Econ.* 68(1986):950–60.
——. "Testing Empirical Restrictions of the Multivariate Flexible Accelerator in a Model of U.S. Agricultural Investment." Paper presented at the AAEA meeting, Logan UT, 1982.

Appendix

Proportional Growth Rate Derivation

The derivation of the proportional rate of growth in output for the multiple output firm with multiple quasi-fixed factors follows.

Given the assumptions on price expectations, the dynamic programming equation for the problem stated in (1) is

(a1)
$$rJ(p, w, c, k, t) = \max_{Y,X,I,\lambda} \{p'Y - w'X - c'k + (I - \delta k)'J_k + \lambda F(Y, X, k, \dot{K}, t) + J_t\},$$

where $\lambda \geq 0$ is the lagrangian multiplier associated with the production technology constraint. Assuming an interior solution the first-order conditions are

$$\text{(a2.1)} \qquad F_{Y_i} = -\frac{p_i}{\lambda^*} \text{ for } i = 1, \ldots, m$$

$$\text{(a2.2)} \qquad F_{X_p} = \frac{w_p}{\lambda^*} \text{ for } p = 1, \ldots, v$$

$$\text{(a2.3)} \qquad F_{\dot{K}_j} = -\frac{J_{k_j}}{\lambda^*} \text{ for } j = 1, \ldots, n$$

$$\text{(a2.4)} \qquad F(Y, X, k, \dot{K}^*, t) = 0.$$

The arbitrage equation can be found by differentiating the dynamic programming equation in (a1) with respect to k to yield

$$\begin{aligned} rJ_k &= p'\frac{\partial Y^*}{\partial k} - w'\frac{\partial X^*}{\partial k} - c + \frac{\partial \dot{K}^{*\prime}}{\partial k}J_k + J_{kk}\dot{K}^* \\ &\quad + \frac{\partial \lambda^*}{\partial k}F(\quad) + \lambda^*\left[F_Y'\frac{\partial Y^*}{\partial k} + F_X'\frac{\partial X^*}{\partial k} + F_k \right. \\ &\quad \left. + F_{\dot{K}}'\frac{\partial \dot{K}^*}{\partial k}\right] + J_{tk} \\ &= (p + \lambda^* F_Y)'\frac{\partial Y^*}{\partial k} - (w - \lambda^* F_X)'\frac{\partial X^*}{\partial k} \\ &\quad + (J_k + \lambda^* F_{\dot{K}})'\frac{\partial \dot{K}^*}{\partial k}\frac{\partial \lambda^*}{\partial k}F(\quad) - c \\ &\quad + J_{kk}\dot{K}^* + \lambda^* F_k + J_{tk}, \end{aligned}$$

and using the first-order conditions in (a2.1) through (a2.4) leads to

$$\text{(a3)} \qquad rJ_k = -c + \lambda^* F_k + J_{kk}\dot{K}^* + J_{tk}.$$

The rate of change in the shadow value of capital can be expressed as

$$\text{(a4)} \qquad \frac{dJ_k(p, w, c, k, t)}{dt} = \dot{J}_k = J_{kk}\dot{K}^* + J_{kt},$$

assuming prices are static ($dp = 0$, $dw = 0$ and $dc = 0$). Thus, the arbitrage equation is

$$\text{(a5)} \qquad rJ_k = \lambda^* F_k - c + \dot{J}_k,$$

which states that the opportunity cost of capital, rJ_k, must equal the instantaneous gain, $\lambda^* F_k - c$, plus the instantaneous capital gain (or loss), $\dot{J}_k$, arising from an additional unit of capital.

The proportional growth in output under dynamic adjustment is derived by totally differentiating $F(Y, X, k, \dot{K}, t)$ to yield

$$\text{(a6)} \qquad \sum_i^m F_{Y_i}dY_i + \sum_p^v F_{X_p}dX_p + \sum_j^n F_{k_j}dK_j + \sum_j^n F_{\dot{K}_j}d\dot{K}_j + \frac{\partial F}{\partial t}dt = 0.$$

Dividing through by $\Sigma_i^m F_{Y_i} Y_i$ and dt, with some rearranging, yields

$$\text{(a7)}\quad \sum_i^m \frac{F_{Y_i} Y_i}{\sum_i^m F_{Y_i} Y_i} \hat{Y}_i = -\left[\sum_p^v F_{X_p} X_p \hat{X}_p + \sum_j^m F_{k_j} k_j \hat{K}_j + \sum_j^m F_{\dot{K}_j} \dot{K}_j \hat{\dot{K}}_j + \frac{\partial F}{\partial t} \right] \frac{1}{\sum_i^m F_{Y_i} Y_i},$$

where the carat indicates the proportional rate of growth (i.e., $\hat{M} = \dot{M}/M$). Following Hulten, the last term in the brackets represents the shift in the multiple-output technology and is defined as $\hat{A}$. Substituting for F_{Y_i}, F_{X_p}, and F_{k_j} using the first-order conditions (a2.1) through (a2.3) and using the arbitrage equation in (a5), which implies

$$F_K = \frac{rJ_k + c - \dot{J}_k}{\lambda^*},$$

leads to (a7) being rewritten as

$$\text{(a8)}\quad \sum_i^m \frac{p_i Y_i}{TR} \hat{Y}_i = \sum_p^v \frac{w_p X_p}{TR} \hat{X}_p - \sum_j^m \frac{J_{kj} \dot{K}_j}{TR} \hat{\dot{K}}_j - \sum_j^m \frac{J_{kj} \dot{K}_j}{TR} \hat{J}_{kj} + \sum_j^m \frac{(rJ_{kj} + c_j) k_j}{TR} \hat{K}_j + \hat{A}.$$

Defining total shadow cost as $TSC = w'X^* + c'k - \dot{K}^{*\prime} J_k - J_t$, and denoting total revenue as $TR = p'Y^*$, equation (a8) can be rewritten by multiplying and dividing through by TSC to yield

$$\text{(a9)}\quad \hat{Y}(t) = \frac{TSC}{TR} \left[\sum_p^v \frac{w_p X_p}{TSC} \hat{X}_p - \sum_j^m \frac{J_{kj} \dot{K}_j}{TSC} \hat{\dot{K}}_j - \sum_j^m \frac{J_{kj} \dot{K}_j}{TSC} \hat{J}_{kj} + \sum_j^m \frac{(rJ_{kj} + c_j) K_j}{TSC} \hat{K}_j \right] + \hat{A},$$

where $\hat{Y}(t) = \Sigma_i^m p_i Y_i / TR\ \hat{Y}_i$. The ratio TSC/TR is the measure of long-run returns to scale allowing for the dynamics of adjustment. Further, define

$$\text{(a10)}\quad \hat{F}_v = \sum_p^v \frac{w_p X_p}{TSC} \hat{X}_p,\ \hat{F}_{q1} = -\sum_j^m \frac{J_{kj} \dot{K}_j}{TSC} \hat{\dot{K}}_j,$$

$$\hat{F}_{q2} = -\sum_j^m \frac{J_{kj} \dot{K}_j}{TSC} \hat{J}_{kj}, \quad \text{and}$$

$$\hat{F}_x = \sum_j^m \frac{(rJ_{kj} + c_j) k_j}{TSC} \hat{K}_j.$$

Using the definition in (a9) in (a10) leads to the proportional growth in output in (2).

Dynamic Decisions Under Risk: Application of Ito Stochastic Control in Agriculture

Greg Hertzler

In agricultural economics, most studies of dynamic decisions under risk have been empirical with less emphasis on theory. In finance, resource economics, and general economics, however, Ito stochastic control is popular for theoretical work. Optimal decisions can be characterized using the powerful Ito stochastic calculus. This paper describes the assumptions and methods of Ito control, constructs a dynamic model of agricultural decisions under risk, and illustrates with four examples.

Key words: agriculture, risk, stochastic calculus, stochastic control.

The art of modeling is the art of striking a bargain. Sometimes tractability must be at the expense of realism. Researchers in finance, natural resource economics, and general economics have struck a favorable bargain by accepting the assumptions and gaining the analytical power of Ito stochastic control. Appendix 1 contains a synopsis of this literature. The purposes of this article are to (*a*) distill the erudite literature on Ito control into a more useful form and (*b*) adapt Ito control to a dynamic theory of agricultural decisions under risk.

In agricultural economics, most studies of dynamic decisions under risk have been empirical (see appendix 1). Ito stochastic control is a tool for constructing the theory to complement these empirical results. An analogy might be made to optimal control without risk. Applications are solved in discrete time by mathematical programming or dynamic programming, but the theory is usually developed in continuous time using optimal control. With risk, applications must be solved in discrete time by dynamic programming, but the theory will almost always be easier to develop in continuous time using Ito control. A more general, but less tractable, approach to theory integrates directly over transition density functions and differentiates the integrals to find optimality conditions (Taylor; Blume, Easley, and O'Hara). Ito control simplifies the stochastic structure of the model and finds optimality conditions using a stochastic calculus. It allows expected utility to be maximized over time subject to multiple and correlated risks. Ito control is popular in finance, general economics, and natural resource economics because little economic realism is sacrificed for a large gain in analytical power.

In this article the assumptions behind Ito stochastic processes are explained, and stochastic calculus and optimal control methods are presented. Then a model is developed which adapts Ito control to the investment, marketing, production, and household consumption decisions of a risk-averse farmer. No single model can cover the many topics within the subject of agricultural decisions under risk. But most models will have the basic structure derived and illustrated here. Other researchers can build on this structure, adapt it to their own models, and derive theoretical results which complement their empirical results.

Ito Stochastic Processes

State variables, sometimes called quasi-fixed factors, distinguish a dynamic model from a static one. State variables cannot adjust instantaneously, as can variable factors, but they do change, unlike fixed factors. Wealth is a state variable common to all farmers. It changes over time with the retention of earnings from net income. Other state variables may include inven-

---

Greg Hertzler is in the Faculty of Agriculture at the University of Western Australia.

An earlier version of this paper was presented to the 1989 Australasian meeting of the Econometric Society.

tories of machinery and livestock, stocks of soil moisture and soil fertility, water tables, minerals, or prices.

A farmer makes decisions at the beginning of each discrete time interval. A decision is risky if a state variable changes unexpectedly once the decision is made. Thus, the change in the state variable is described by a stochastic difference equation:

$$S_\tau - S_t = f(t, S_t, c_t, \xi_t)[\tau - t],$$

where S is a state variable; c is a vector of control variables; ξ is a vector stochastic process of dimensions $n \times 1$; t and τ are current and future times; and $\tau - t$ is the length of each time interval. Three assumptions convert the difference equation into an Ito differential equation.

Assumption 1: Markov property. The current state summarizes all relevant information. The probability of making a transition conditioned upon past and present states of the system or past and present stochastic events equals the probability of making a transition conditioned upon just the current state. The past and the future are statistically independent.

Assumption 2: Continuous time. The difference equation is approximated by a differential equation is continuous time.

Assumption 3: Rapid events. Stochastic events occur "rapidly." For example, weather and prices can be difficult to predict from one growing season to the next.[1]

These three assumptions have several implications. The Markov property and continuous time together imply that the approximating differential equation is linear in the stochastic process (Horsthemke and Lefever, p. 97; Arnold, chap. 9).

$$S_\tau - S_t = [\delta(t, S_t, c_t) + \sigma(t, S_t, c_t)\xi_t][\tau - t] + o(\tau - t).$$

The expected change in the state per unit of time is δ. The standard deviation, σ, is a vector function of dimension $1 \times n$. It can be a function of the control and state variables or it can be heteroscedastic as a function of time. Special cases include Kalman filtering, and multiplicative, and additive risks (Mangel, p. 33; Arnold, p. 206; Fleming and Rishel, p. 135; Kendrick, chaps. 5, 6). The order function, $o(\tau - t)$, is a remainder which goes to zero faster than time interval $\tau - t$ approaches dt in the limit of continuous time.

Continuous time is a simple assumption in a deterministic model. By the fundamental theorem of calculus, a difference equation converges in the limit to a unique differential equation. There is only one calculus for deterministic equations. But the limit of a stochastic difference equation is not unique. If the stochastic difference equation is evaluated at the midpoint of each time interval, it converges to a Stratonovich differential equation (Wong and Zakai). If it is evaluated at the beginning of each time interval, it converges to an Ito differential equation (Maruyama). Two different stochastic calculi result from the two approximations (Sethi and Lehoczky; Horsthemke and Lefever, p. 101; Schuss, p. 93). The Stratonovich calculus has the same rules as ordinary calculus (Stratonovich). Unfortunately the Markov property is destroyed. The state of the system at the beginning of a time interval does not summarize all the information necessary for approximating at the midpoint. The Ito calculus has different rules of integration and differentiation, but it preserves the Markov property by approximating at the beginning of each time interval (Ito 1944, 1951a, b).

The stochastic processes must be identically and independently distributed at each point in time. If stochastic processes were not independent but autocorrelated, past events would contain information not summarized by the current state and the Markov property would be violated. For rapid events, the first two moments become sufficient statistics (Feller, p. 335; Arnold, pp. 39, 156; Malliaris and Brock, p. 99; Horsthemke and Lefever, p. 72). The first, second, and higher moments of the change in the state variable are

$$(1) \quad E\{S_\tau - S_t | S_t = s_t\} = \delta(t, S_t, c_t)[\tau - t] + o(\tau - t);$$

$$E\{[S_\tau - S_t]^2 | S_t = s_t\} = \sigma(t, S_t, c_t)\Omega\sigma'(t, S_t, c_t)[\tau - t] + o(\tau - t);$$

$$E\{[S_\tau - S_t]^{2+\alpha} | S_t = s_t\} = o(\tau - t).$$

Here, Ω is the contemporaneous correlation matrix and $\sigma\Omega\sigma'$ is the covariance, α is a positive parameter, and expectations are conditioned on a known current stock, s_t. As $\tau - t$ approaches dt in the limit, the order terms vanish, the first moment becomes the drift term, δdt, the second moment becomes the diffusion term, $\sigma\Omega\sigma' dt$,

[1] Merton (1982) also describes "rare" events. For example, machines fail and agricultural commodity programs are revised only rarely. The theory of rapid events is more developed and is used in the analysis to follow.

and higher moments go to zero, regardless of the underlying probability distribution.

Finally, the ordinary stochastic process, ξ, must be replaced by white noise, ϵ (Horsthemke and Lefever, p. 59). The ordinary stochastic process has a finite variance which prevails over each discrete time interval. As time is divided into shorter and shorter intervals in the passage to continuous time, this finite variance would be parcelled out and the variance in each short interval would go to zero. For the differential equation to remain stochastic, the variance must increase to infinity as time becomes continuous. An infinite variance, an expected value of zero and no autocorrelation is a description of white noise.[2]

$$E\{\epsilon_t\} = 0;$$

$$E\{\epsilon_t\epsilon_\tau'\} = \begin{cases} \Omega/[\tau - t] \text{ goes to } \infty \text{ as } \tau - t \text{ goes to } dt; \\ 0 \text{ for } \tau \neq t. \end{cases}$$

To see how white noise replaces an ordinary stochastic process in the passage to continuous time, consider a special kind of state variable, Z, which has a drift of zero, a standard deviation of unity and a normally distributed stochastic process:

$$Z_\tau - Z_t = \xi_t[\tau - t] + o(\tau - t).$$

By equation (1), the first moment is $o(\tau - t)$ and the second moment is $\Omega[\tau - t] + o(\tau - t)$. Thus, $\xi\xi'$ must equal $\Omega/[\tau - t]$ and the change in Z converges in distribution to white noise as time becomes continuous.

$$dZ = \epsilon dt. \tag{2}$$

In (2), Z is called Brownian motion or a Weiner process. Its differential over time is normally distributed white noise.

Finally, an Ito differential equation is defined by taking the limit of the difference equation for state variable S as $\tau - t$ becomes dt and ordinary stochastic process, ξ, becomes white noise, ϵ, then replacing white noise over time by the differential of the Weiner process.[3]

$$dS = \delta(t, S_t, c_t)dt + \sigma(t, S_t, c_t)dZ. \tag{3}$$

The Ito differential equation retains the essential character of the original difference equation. Time is asymmetric. Decisions are made at the beginning of each infinitely short time interval based on information summarized by the current state. The state variable is not differentiable with respect to time in the ordinary sense. It evolves stochastically and is differentiable only by stochastic calculus.

Ito Stochastic Calculus and Control

Like ordinary calculus, Ito stochastic calculus includes integration and differentiation. Integration is useful (Arnold, chaps. 7, 8), but differentiation is essential. Let variable X be a function of both time and the stochastic state variable, or $X = f(t, S)$, and take the Taylor expansion.

$$\begin{aligned} X_\tau - X_t = {} & f_t[\tau - t] + f_S[S_\tau - S_t] \\ & + 1/2[f_{tt}[\tau - t]^2 + 2f_{tS}[\tau - t][S_\tau - S_t] \\ & + f_{SS}[S_\tau - S_t]^2] + O([\tau - t]^3) \\ & + O([S_\tau - S_t]^3), \end{aligned}$$

where f_t, f_S, f_{tt}, f_{tS}, and f_{SS} are partial derivatives and the terms $O([\cdot]^3)$ are order functions which converge to nonzero constants.

Ito's lemma (Ito 1951a, b) simplifies the Taylor expansion. Like differentiation by ordinary calculus, only first-order terms must be retained in the passage to continuous time. Terms with $[\tau - t]^2$ and $[\tau - t][S_\tau - S_t]$ are of second order and vanish in the limit. However, the second moment, $[S_\tau - S_t]^2$, is actually of first order in $\tau - t$ according to equation (1). The limit of the Taylor expansion is the stochastic differential equation for X which, with the aid of equation (3), can be written in either of two forms:

$$\begin{aligned} dX &= f_t dt + f_S dS + 1/2 f_{SS} dS^2 \\ &= [f_t + f_S\delta(t, S, c) \\ &\quad + 1/2 f_{SS}\sigma(t, S, c)\Omega\sigma'(t, S, c)]dt \\ &\quad + f_S\sigma(t, S, c)dZ. \end{aligned} \tag{4}$$

Three simple rules convert the second moment of the state variable, dS^2, into the diffusion term, $\sigma\Omega\sigma' dt$:

$$dt^2 = 0; \quad dtdZ = 0; \quad dZdZ' = \Omega dt. \tag{5}$$

When differential equation (3) is squared, all terms with dt^2 go to zero, including $dtdZ$ which equals ϵdt^2. Although $dZdZ'$ equals $\epsilon\epsilon' dt^2$, it is not zero because $\epsilon\epsilon'$ equals Ω/dt.

The trademark of an Ito derivative is the diffusion for S inserted into the drift for X. For

[2] White noise can have different probability distributions including normal and Poisson (Gel'fand and Vilenkin). Normal distributions result in Weiner processes and Poisson distributions result in Poisson processes and model rapid and rare events, respectively.

[3] Rare events could be included by adding the term σdP where σ is a standard deviation and dP is the differential of a Poisson process (Merton 1971; Malliaris and Brock, p. 121; Mangel, p. 22).

example, if $X = f(t, S)$ were concave, variance in S would be expected to decrease X. This trademark results from the Markov property in which expectations are formed at the beginning of each small time interval. Examples of Ito differentiation can be found in Kamien and Schwartz (chap. 21) and Malliaris and Brock (pp. 89, 220). Appendix 2 contains the differentiation formula for when S is a vector of state equations.

Like deterministic optimal control, Ito control maximizes an objective function subject to differential equations for the state variables. The objective function of a farmer who wishes to maximize his expected utility is

$$(6)\quad J(S_0) = \operatorname*{Max}_{c} E \left\{ \int_0^T e^{-\rho t} U(S_t, c_t)dt + e^{-\rho T} V(S_T) \,\middle|\, S_0 = s_0 \right\}.$$

Maximization is subject to the stochastic evolution of the state variable in equation (3). The farmer's control and state variables are c and S; his direct utility functions are U and V; his indirect utility after optimization is J; his rate of time preference is ρ; and his planning horizon is T. In a typical model, the farmer would maximize the expected utility of current consumption and terminal wealth, but many other control and state variables are possible.

Either dynamic programming or a stochastic maximum principle can optimize equation (6) (Malliaris and Brock, pp. 108, 112, 118). Dynamic programming is more common, and optimality conditions are derived from the Ito version of the Hamilton-Jacobi-Bellman (HJB) equation:

$$(7)\quad 0 = J_t + \operatorname*{Max}_{c} \{e^{-\rho t}U(S, c) + J_S\delta(t, S, c) + 1/2 J_{SS}\sigma(t, S, c)\Omega\sigma'(t, S, C)\},$$

where J_t, J_S, and J_{SS} are partial derivatives and the HJB equation is a partial differential equation in t and S. It has end condition $J(T, S_T) = e^{-\rho T}V(S_T)$. The expression in brackets to be maximized is a dynamic certainty equivalent denominated in utils. Its first term is current direct utility; its second term is the dynamic cost of an expected change in the state; its third term is the dynamic risk premium.

Because the HJB equation is derived by Ito differentiation it contains the covariance of the state variable in its risk premium. This gives Ito control all the power of mean-variance analysis without the restrictive assumptions. The only assumptions required are rapid uncertainty and the Markov property in continuous time. The first two moments become sufficient statistics and the utility functions can be of any form, allowing all types of risk preferences. The second partial derivative, J_{SS}, is zero or negative for a risk-neutral or a risk-averse farmer and changes endogenously with the level of the state.

Control variables, c, are chosen by differentiating the HJB equation:

$$(8)\quad 0 = e^{-\rho t}U_c + J_S\delta_c + J_{SS}\sigma\Omega\sigma'_c,$$

where U_c is marginal direct utility, δ_c is the partial derivative of the expected change, and $\sigma\Omega\sigma'_c$ is one-half the partial derivative of the covariance where σ'_c is an $n \times 1$ vector of partial derivatives of the standard deviation vector. To make his decision, a farmer compares discounted marginal utility to the marginal dynamic costs of an expected change in the state and a marginal risk premium.

Another optimality condition describes the shadow price, or costate, J_S. Just as the state variable changes stochastically over time, so does the costate. Its differential equation is presented in appendix 2.

A Model for Agriculture

A farmer faces many risks from production, from prices, and from investments. No single model can include them all. But every model must consider the farmer's bottom line, risky income which makes the accumulation of wealth stochastic. A risk-averse farmer may wish to maximize his expected utility subject to his stochastic change in wealth:

$$(9)\quad J(W_0) = \operatorname*{Max}_{q,c} E \left\{ \int_0^T e^{-\rho t}U(q)dt + e^{-\rho T}V(W_T) \,\middle|\, W_0 = w_0 \right\},$$

subject to

$$(10)\quad dW = \left[\delta_w W + \sum_i (\delta_i - \delta_w)p_i A_i - \sum_i p_i g_i(A, c) + \pi - p_q q\right]dt + \sum_i p_i A_i \sigma_i dz_i - \sum_i p_i s_i(A, c)dZ_i + d\pi,$$

where U and V are direct utility of consumption and terminal wealth; J is indirect utility of wealth;

q is consumption at price p_q; c is a vector of production decisions to be defined in later examples; ρ is the farmer's rate of time preference; W is wealth which can be invested off-farm at the risk-free rate δ_w; A_i is the inventory of an agricultural asset valued at price p_i and expected to receive premium $\delta_i - \delta_w$ above the risk-free rate; g_i is the physical rate of degradation of an inventory; π is the revenue from production above variable costs, or gross margin; σ_i and s_i are standard deviations of returns to assets and of physical degradation; dz_i, and dZ_i are Weiner processes; and $d\pi$ is the stochastic change in the gross margin.

The stochastic change in wealth, equation (10), is derived in appendix 3. It is a general equation that must be specialized for a particular topic in risk. Investment in financial assets will treat the term $(\delta_i - \delta_w)p_iA_i$ as real capital gains. Investment in depreciating assets, such as machinery, may treat this same term as fixed costs. Negative δ_i is a rate of depreciation, and δ_w is the rate of interest on investment. The term $p_iA_i\sigma_i dz_i$ is risk from capital gains or depreciation. Investment in degradable assets, such as soil which erodes and livestock which dies, will treat the term p_ig_i as a user cost or quasi-fixed cost. The amount of the asset used, g_i, will cost p_i to replace. Degradation is risky because of the term $p_is_idZ_i$. Most important, however, gross margin, π, and its stochastic change, $d\pi$, must be specified. Gross margin could include many combinations of stochastic yields and prices. A few combinations are illustrated in the following examples.

Example 1: Farmland Investment

The capitalization approach to farmland valuation has been investigated by many authors including Burt, Alston, and Featherstone and Baker. Using Ito control, this approach can be generalized to include risk and risk preferences.

Assume the farmer's only asset is land, L, valued at price p_ℓ and expected to appreciate at rate δ_ℓ. Assume the land does not degrade physically. Also assume the gross margin is nonstochastic and equals the gross margin per hectare times the number of hectares of land:

$$\pi = (p_yY(x) - p_xx)L,$$

where Y is yield per hectare as a function of variable input x; p_y and p_x are prices for yield and the variable input. With these assumptions, the change in wealth, equation (10), becomes

$$dW = [\delta_wW + (\delta_\ell - \delta_w)p_\ell L + (p_yY - p_xx)L - p_qq]dt + p_\ell L\sigma_\ell dz_\ell.$$

Optimal farmland investment will be derived from the Hamilton-Jacobi-Bellman (HJB) equation (7). The state variable denoted by S in the HJB equation corresponds to wealth. The control vector, c, contains the variable input and hectares of land. The drift term, δdt, is the first moment, $E\{dW\}$, and the diffusion term, $\sigma\Omega\sigma' dt$, equals the second moment, $E\{dW^2\}$.

$$\begin{aligned}\delta dt &= [\delta_wW + (\delta_\ell - \delta_w)p_\ell L + (p_yY - p_xx)L - p_qq]dt;\\ \sigma\Omega\sigma' dt &= \delta^2dt^2 + 2\delta p_\ell L\sigma_\ell dtdz_\ell + (p_\ell L\sigma_\ell)^2dz_\ell^2\\ &= (p_\ell L\sigma_\ell)^2dt.\end{aligned}$$

According to the rules in (5), dz_ℓ^2 is a first-order term equal to time increment dt. But dt^2 and $dtdz_\ell$ are second-order terms which vanish in the limit of continuous time.

From equation (8), the optimality condition for land equals J_W times the derivative of drift plus J_{WW} times one-half the derivative of diffusion.

$$0 = J_W[(\delta_\ell - \delta_w)p_\ell + p_yY - p_xx] + J_{WW}L(p_\ell\sigma_\ell)^2.$$

This can be solved for the demand for farmland.

$$L = [p_yY - p_xx - (\delta_w - \delta_\ell)p_\ell] / [-J_{WW}/J_W](p_\ell\sigma_\ell)^2. \tag{11}$$

The numerator is the gross margin per hectare minus the opportunity cost of investment after expected capital gains. The denominator is the variance of land prices weighted by the farmer's coefficient of absolute risk aversion, $-J_{WW}/J_W$. A risk-averse farmer has negative J_{WW} and invests in farmland if the gross margin exceeds the expected opportunity cost. The greater his risk aversion the lower a farmer's demand for land.

Further insight comes from solving for the price of farmland:

$$p_\ell = [p_yY - p_xx - L[-J_{WW}/J_W](p_\ell\sigma_\ell)^2]/(\delta_w - \delta_\ell).$$

To calculate the maximum price he would be willing to bid, a risk-neutral farmer divides the gross margin by the real rate of interest after expected capital gains. An aspiring farmer who does not yet own farmland has no risk exposure. He may be risk averse but would initially bid as though he were risk neutral. As he accumulates farmland his risk exposure increases and he lowers his bid. If the gross margin were risky he would be even more conservative.

This stochastic price equation implies that farmers who are very averse to risk might be willing to purchase some land but farmers who are less averse will purchase more. In addition to economies-of-scale, degrees of risk aversion may influence farm size.

Example 2: Forward Selling

Many authors have investigated forward selling through forward contracts or futures markets. Kahl; Bond, Thompson, and Geldard; Thompson and Bond, and Robison and Barry (chap. 10) used mean-variance analysis to determine the optimal proportion of yields to hedge. Using Stein's theorem, Grant extended the results to an expected utility model with bivariate, normally distributed risks. Using Ito control, the results can be extended even further to a dynamic expected utility model with multiple sources of correlated risks.

Assume the farmer has a fixed land area which does not appreciate in value. All his financial investments are risk-free. The gross margin, however, is now stochastic and has a term for hedging income:

$$\pi = p_y Y(x) - p_x x - (p_f - p_c)F.$$

The farmer hedges quantity F by either a forward or futures contract and receives contract price p_c. With a forward contract he must deliver at harvest time or, equivalently, sell all his yield and purchase enough at future price p_f to make the promised delivery. With a futures contract, he purchases an offsetting contract before the original contract matures. Future price, p_f, equals spot price, p_y, for a forward contract. The future price should converge to the spot price for a futures contract but may be subject to a different stochastic influence leading to basis risk. Because of spot and futures price risks, the gross margin has an Ito derivative as defined by equation (A4) in appendix 2;

$$d\pi = dp_y Y - dp_f F.$$

In the finance literature, it is typical to assume price expectations that are lognormal. In other words, a farmer expects prices to be nonnegative and their percentage change to be normally distributed:

$$dp_y/p_y = [\delta_y + \sigma_y \epsilon_y]dt = \delta_y dt + \sigma_y dz_y;$$

$$dp_f/p_f = [\delta_f + \sigma_f \epsilon_f]dt = \delta_f dt + \sigma_f dz_f.$$

Expected rates of change, δ_y and δ_f are forecast with errors $\sigma_y \epsilon_y$ and $\sigma_f \epsilon_f$, where the σ's are standard deviations and the ϵ's are normally distributed white noise. By equation (2), ϵdt is the change in a Weiner process, dz. The Weiner processes for the spot and futures prices may be highly correlated.

After substituting in the gross margin, its Ito derivative and price expectations, the change in wealth, equation (10), becomes

$$dW = [\delta_w W + p_y(1 + \delta_y)Y - p_x x - (p_f(1 + \delta_f) - p_c)F - p_q q]dt + p_y Y \sigma_y dz_y - p_f F \sigma_f dz_f.$$

As in the previous example, the drift term, δdt, is the expected change in wealth. In this example, however, there are two sources of risk and the diffusion term, $\sigma\Omega\sigma' dt$, is the product of matrices.

$$\sigma\Omega\sigma' dt = [p_y Y\sigma_y; -p_f F\sigma_f]\begin{bmatrix} dz_y \\ dz_f \end{bmatrix}[dz_y; dz_f]\begin{bmatrix} p_y Y\sigma_y \\ -p_f F\sigma_f \end{bmatrix} = [p_y Y\sigma_y; -p_f F\sigma_f]\begin{bmatrix} 1 & \omega_{yf} \\ \omega_{yf} & 1 \end{bmatrix}\begin{bmatrix} p_y Y\sigma_y \\ -p_f F\sigma_f \end{bmatrix}dt.$$

Using the rules in (5), the product of Weiner increments, $dz_y dz_f$, equals $\omega_{yf} dt$ where ω_{yf} is the correlation coefficient.

Optimality condition (8) is applied by differentiating drift with respect to F and multiplying by J_W. To this is added the derivative of σ' premultiplied by $J_{WW}\sigma\Omega$;

$$0 = -J_W[p_f(1 + \delta_f) - p_c] + J_{WW}[F(p_f\sigma_f)^2 - Yp_y p_f \sigma_y \sigma_f \omega_{yf}].$$

The demand for futures is found by solving for F:

$$(12)\quad F = Y(p_y\sigma_y\omega_{yf})/p_f\sigma_f + [p_c - p_f(1 + \delta_f)]/[-J_{WW}/J_W](p_f\sigma_f)^2.$$

The first term on the right-hand side is the demand for futures as a hedge. The second term is speculative demand. Suppose the futures contract is for a completely different commodity than the one produced and the spot and futures prices are uncorrelated. A risk-averse farmer may still speculate if the contract price exceeds the expected futures price. The more risk-averse a farmer, the less will be his speculative demand. Positively correlated spot and futures prices increase the demand for futures as a hedge. Prices may never be perfectly correlated because of basis risk, and the farmer will hedge only a portion

of his yield. A forward contract, however, is a special case in which spot and futures prices are identical. Price risk is eliminated. The farmer hedges all his yield and uses contract price p_c to calculate the marginal value product in making his production decisions. If yields were stochastic, the decisions of a risk-averse farmer would be more complex and he might not hedge all of his yield.

Example 3: Production from Nutrient Stocks

Typically, studies of production under risk consider only variable inputs. This is true for studies of fertilizer applications, as an example (Rosegrant and Roumasset, SriRamaratnam et al.). Most nutrients, however, are quasi-fixed stocks which carry over from one year to the next (Lanzer and Paris). The rate of carryover is stochastic, depending upon rainfall. Yields are a stochastic function of these nutrient stocks and other variables beyond the farmer's control such as soil moisture, temperature, and pest attacks. Thus, the gross margin is stochastic because of yield:

$$\pi = p_y Y(N, x) - p_x x;$$

$$d\pi = p_y dY.$$

Yield has many stochastic influences and evolves according to a complex differential equation, but the drift and deviation terms of this equation can be summarized as functions of nutrient stocks, N:

$$dY = \delta_Y(N)dt + \sigma_Y(N)dZ_Y.$$

The change in yields is linear in the stochastic process. This imparts the same desirable properties postulated by Just and Pope (1978, 1979) for stochastic yields in a static model.

The assumptions about nutrient degradation, gross margins, and yield transform the change in wealth, equation (10), into

$$dW = [\delta_w W + (\delta_n - \delta_w)p_n N - p_n g(N) + p_y(Y(N, x) + \delta_Y(N)) - p_x x - p_q q]dt + p_n N\sigma_n dz_n - p_n s_N dZ_N + p_y \sigma_Y(N)dZ_Y.$$

The drift term now contains investment and degradation costs for nutrients. Expectations must be formed about the price of nutrients, the degradation of nutrients, and about yield. Degradation and yield both depend on the weather and may be highly correlated in the diffusion term:

$$\sigma\Omega\sigma' dt = [p_n N\sigma_n; -p_n s_N; p_y\sigma_Y(N)] \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & \omega_{NY} \\ 0 & \omega_{NY} & 1 \end{bmatrix} \begin{bmatrix} p_n N\sigma_n \\ -p_n s_N \\ p_y\sigma_Y(N) \end{bmatrix} dt.$$

The derivatives of drift and diffusion are substituted into equation (8) to find the optimality condition for nutrients which is then rearranged as

(13)
$$p_y(\partial Y/\partial N + \partial\delta_Y/\partial N) = p_n(\delta_w + \partial g/\partial N - \delta_n) + N[-J_{WW}/J_W](p_n\sigma_n)^2 + [-J_{WW}/J_W][(p_y\sigma_Y)^2 - p_n p_y s_N \sigma_Y \omega_{NY}](\partial\sigma_Y/\partial N)/\sigma_Y.$$

The farmer compares the expected marginal-value product on the left-hand side to the marginal investment cost and marginal risk premiums on the right-hand side. The marginal investment cost depends on an effective rate of return on investment. This rate equals the interest rate plus the marginal rate of degradation minus the expected rate of change in the nutrient price. An easily leached nutrient, such as nitrogen, is almost a variable input because the marginal rate of degradation is nearly one. A slowly leached nutrient is almost a fixed cost because the marginal rate of degradation is nearly zero. If he expects its price to increase, the farmer will apply more nutrient to carry into the future.

A risk-neutral farmer sets the marginal risk premiums to zero but his decisions may appear to be risk averse (Just). Stochastic nutrients modify the expected marginal value product through the term δ_Y. With no risk, the farmer would expect the marginal value product to be $p_y\partial Y/\partial N$. But with risky nutrients the expected marginal value product may increase if $\partial\delta_Y/\partial N$ is positive. The farmer would demand more. A risk-averse farmer will behave the same as a risk-neutral farmer if fertilizer prices are certain and the nutrient neither increases nor decreases yield risk. He will demand less than a risk-neutral farmer if the nutrient price is risky, and he will demand more if the nutrient decreases yield risk with $(\partial\sigma_Y/\partial N)/\sigma_Y$ negative. Nutrient availability and yields may have a negative covariance in the marginal risk premium. Unexpected rainfall may cause rapid degradation and lower yields. Costs would be unexpectedly high and returns unexpectedly low, increasing the variance of income and the incentive of a risk-averse farmer to apply extra nutrients.

Example 4: Household Demand

In example 1, the farmer chose whether to invest his wealth at a risk-free rate or buy farmland. But there is a third choice, consume rather than invest. The farmer equates the discounted marginal utility of consumption with the marginal utility of wealth multiplied by the price of the consumption good:

$$e^{-\rho_t}\partial U/\partial q = J_W p_q.$$

Using equation (A9) from appendix 2, it can be shown that the farmer expects the marginal utility of wealth to decline at the risk-free rate of interest or, in other words, to be constant in real terms. Suppose the farmer's marginal utility of wealth is constant and his rate of time preference equals the rate of interest. Then, perhaps, demand could be estimated as if it were static.

A more rigorous, but less flexible, approach would estimate a closed-form demand equation. A closed-form equation can be integrated analytically to find indirect utility. Merton (1971) proved that a closed-form is linear if and only if the direct utility function belongs to the hyperbolic absolute risk aversion (HARA) class of functions. This class includes many popular utility functions, such as the Stone-Geary function,

$$U(q) = \beta(q - \gamma)^{\alpha}.$$

To find closed-form demand, first U is differentiated and substituted into the optimality condition. Then the optimality condition is solved for q:

$$q = [p_q e^{\rho_t} J_W/\alpha\beta]^{1/(\alpha-1)} + \gamma.$$

Next, q and the demand for land, L, from equation (11) are substituted into the HJB equation, which is simplified,

$$0 = J_t + (1 - \alpha)\beta e^{-\rho_t}[p_q e^{\rho_t} J_W/\alpha\beta]^{\alpha/(\alpha-1)}$$
$$- 1/2[J^2 w/J_{WW}]m^2 + J_W[\delta_w W - p_q\gamma].$$

The coefficient m is the gross margin per hectare of land above interest on investment, standardized for risk,

$$m = [p_y Y - p_x x - (\delta_w - \delta_\ell)p_\ell]/p_\ell\sigma_\ell.$$

The HJB equation is a partial differential equation in wealth and time. Assuming a zero utility of terminal wealth, Merton (1973b) integrated to find indirect utility,

$$J(W, t) = \beta e^{-\rho_t}[(1 - \alpha)(1 - e^{-r(T-t)/(1-\alpha)})/r]^{(1-\alpha)}$$
$$\cdot [W/p_q - \gamma(1 - e^{-\delta_w(T-t)})/\delta_w]^{\alpha}.$$

Rate r is the farmer's rate of time preference above a risk-adjusted interest rate:

$$r = \rho - \alpha[\delta_w + 1/2m^2/(1 - \alpha)].$$

Finally, indirect utility, J, is differentiated with respect to wealth and substituted into the optimality condition for q to get a dynamic linear-expenditure equation:

$$(14) \quad p_q q = r[W + p_q\gamma(1 - e^{-\delta_w(T-t)})/\delta_w]/$$
$$[(1 - \alpha)(1 - e^{-r(T-t)/(1-\alpha)})] + p_q\gamma.$$

This dynamic demand equation differs from its static counterparts in having wealth as an argument instead of income and depending explicitly on the farmer's time horizon, rate of time preference, rate of interest and exposure to risk. Because demand is a closed-form solution, movements in commodity prices or reductions in risk translate exactly into the change in utility. There is no need to calculate changes in consumer's surplus as a proxy. Finally, more general utility functions including utility of terminal wealth, more sources of risk, and multiple commodities are possible in a dynamic linear-expenditure system.

Conclusions

In agricultural economics, most studies of dynamic decisions under risk are empirical. Fewer studies are theoretical, perhaps because the models are difficult to analyze. Ito stochastic control is an ideal tool for theoretical analysis. The crucial assumptions are the Markov property and continuous time. The Markov property is natural for economic models because decisions are made at the beginning of each time interval. The limit of continuous time is no more restrictive than in deterministic models. With these and an added assumption of rapid stochastic events, the first and second moments of a stochastic process become sufficient statistics. Ito control has the power of mean-variance analysis without objectionable assumptions about probability distributions or utility functions.

A model for agricultural decisions under risk was derived and proposed as a basic model. Then the model was adapted for four topics: a farmer's investment in risky assets, marketing with risky prices, production from stock inputs that degrade stochastically, and dynamic household demand. A few results from the literature were strengthened and new results were obtained. The capitalization approach to farmland valuation was

generalized to include risk and risk preferences. Mean-variance and variance decomposition results for optimal hedging decisions were strengthened by the less restrictive assumptions of Ito control. New results for the optimal carryover of risky nutrients were derived. And a dynamic linear expenditure system under risk was presented. These topics were chosen to demonstrate the methods of Ito calculus and Ito control.

Further topics might include correlated prices and yields, options markets, share-rent versus cash-rent leases, crop insurance, soil erosion, salinization, machinery repair and replacement, livestock replacement and breeding, weed and pest control, commodity programs, buffer stocks, international trade under risk, flexible demand systems, and stochastic dynamic duality.

[Received February 1987; final revision received January 1991.]

References

Abel, A. B. "Optimal Investment Under Uncertainty." *Amer. Econ. Rev.* 73(1983):228–33.

Alston, J. M. "An Analysis of Growth of U.S. Farmland Prices, 1963–82." *Amer. J. Agr. Econ.* 68(1986): 1–9.

Anderson, P., and J. G. Sutinen. "Stochastic Bioeconomics: A Review of Basic Methods and Results." *Marine Resour. Econ.* 1(1984):117–36.

Antle, J. M., and S. A. Hatchett. "Dynamic Input Decisions in Econometric Production Models." *Amer. J. Agr. Econ.* 68(1986):937–49.

Arnold, L. *Stochastic Differential Equations: Theory and Applications.* New York: John Wiley & Sons, 1974.

Black, F., and M. Scholes. "The Pricing of Options and Corporate Liabilities." *J. Polit. Econ.* 81(1973): 637–54.

Blume, L., D. Easley, and M. O'Hara. "Characterization of Optimal Plans for Stochastic Dynamic Programs." *J. Econ. Theory* 28(1982):221–34.

Bond, G. E., S. R. Thompson, and J. M. Geldard. "Basis Risk and Hedging Strategies for Australian Wheat Exports." *Aust. J. Agr. Econ.* 29(1985):199–209.

Burt, O. R. "Econometric Modeling of the Capitalization Formula for Farmland Prices." *Amer. J. Agr. Econ.* 68(1986):10–26.

Burt, O. R., W. W. Koo, and N. J. Dudley. "Optimal Stochastic Control of U.S. Wheat Stocks and Exports." *Amer. J. Agr. Econ.* 62(1980):172–87.

Chang, F.-R. "The Inverse Optimal Problem: A Dynamic Programming Approach." *Econometrica* 56(1988): 147–72.

Chow, G. C. "Optimum Control of Stochastic Differential Equation Systems." *J. Econ. Dynamics and Control* 1(1979):143–75.

Dixon, B. L., and R. E. Howitt. "Resource Production Under Uncertainty: A Stochastic Control Approach to Timber Harvest Scheduling." *Amer. J. Agr. Econ.* 62(1980):499–507.

Featherstone, A. M., and T. G. Baker. "An Examination of Farm Sector Real Asset Dynamics: 1910–85." *Amer. J. Agr. Econ.* 69(1987):532–46.

Feller, W. *An Introduction to Probability Theory and Its Applications,* vols. 1, 2. New York: John Wiley & Sons, 1968, 1971.

Fleming, W. H., and R. W. Rishel. *Deterministic and Stochastic Optimal Control.* New York: Springer-Verlag, 1975.

Grant, D. "Theory of the Firm with Joint Price and Output Risk and a Forward Market." *Amer. J. Agr. Econ.* 67(1985):630–35.

Gel'fand, I. M., and N. Ya. Vilenkin. *Applications of Harmonic Analysis.* New York: Academic Press, 1964.

Horsthemke, W., and R. Lefever. *Noise-Induced Transitions: Theory and Applications in Physics, Chemistry and Biology.* New York: Springer-Verlag, 1984.

Ito, K. "On a Formula Concerning Stochastic Differentials." *Nagoya Math J.* 3(1951a):55–65.

——. "On Stochastic Differential Equations." *Memoirs of the American Mathematical Society.* Rhode Island: American Mathematical Society, 1951b.

——. "Stochastic Integrals." *Proced. Imperial Academy* 20(1944):519–24.

Just, R. E. "Risk Aversion Under Profit Maximization." *Amer. J. Agr. Econ.* 57(1975):347–52.

Just, R. E., and R. D. Pope. "Production Function Estimation and Related Risk Considerations." *Amer. J. Agr. Econ.* 61(1979):277–84.

——. "Stochastic Specification of Production Functions and Economic Implications." *J. Econometrics* 7(1978): 67–86.

Kahl, K. H. "Determination of the Recommended Hedging Ratio." *Amer. J. Agr. Econ.* 65(1983):603–5.

Kamien, M. I., and N. L. Schwartz. *Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management.* New York: North-Holland Publishing Co., 1981.

Karlin, S., and H. M. Taylor. *A First Course in Stochastic Processes.* New York: Academic Press, 1975.

Karp, L. S. "Methods for Selecting the Optimal Dynamic Hedge When Production is Stochastic." *Amer. J. Agr. Econ.* 69(1987):645–57.

Karp, L. S., and C. A. Pope, III. "Range Management Under Uncertainty." *Amer. J. Agr. Econ.* 66(1984):437–46.

Kendrick, D. *Stochastic Control for Economic Models.* New York: McGraw-Hill Book Co., 1981.

Kennedy, J. O. S. *Dynamic Programming: Applications to Agriculture and Natural Resources.* London: Elsevier, 1986.

Lanzer, E. A., and Q. Paris. "A New Analytical Framework for the Fertilization Problem." *Amer. J. Agr. Econ.* 63(1981):93–103.

Malliaris, A. G. "Ito's Calculus in Financial Decision Making." *SIAM Rev.* 25(1983):481–96.

Malliaris, A. G., and W. A. Brock. *Stochastic Methods in*

Economics and Finance. New York: North-Holland Publishing Co., 1982.

Mangel, M. *Decision and Control in Uncertain Resource Systems*. Orlando FL: Academic Press, 1985.

Maruyama, G. "Continuous Markov Processes and Stochastic Equations." *Rendiconti del Circolo Matematico di Palermo*, Series 2, 4(1955):48–90.

McGuckin, J. T., C. Mapel, R. Lansford, and T. Sammis. "Optimal Control of Irrigation Scheduling Using a Random Time Frame." *Amer. J. Agr. Econ.* 69(1987): 123–33.

Merton, R. C. "An Asymptotic Theory of Growth Under Uncertainty." *Rev. Econ. Stud.* 42(1975):375–93.

——. "An Intertemporal Capital Asset Pricing Model." *Econometrica* 41(1973a):867–87.

——. *Continuous-Time Finance*. London: Basil Blackwell, 1990.

——. "Erratum." *J. Econ. Theory*. 6(1973b):213–14.

——. "On the Mathematics and Economics Assumptions of Continuous-Time Models." *Financial Economics: Essays in Honour of Paul Cootner*, ed. W. F. Sharpe and C. M. Cootner, pp. 19–51. Englewood Cliffs: Prentice-Hall, 1982.

——. "Optimum Consumption and Portfolio Rules in a Continuous-Time Model." *J. Econ. Theory* 3(1971): 373–413.

Pindyck, R. S. "Adjustment Costs, Uncertainty and the Behavior of the Firm." *Amer. Econ. Rev.* 72(1982):415–27.

——. "The Optimal Production of an Exhaustible Resource When Price Is Exogenous and Stochastic." *Scand. J. Econ.* 83(1981):279–88.

——. "Uncertainty and Exhaustible Resource Markets." *J. Polit. Econ.* 88(1980):1203–25.

——. "Uncertainty in the Theory of Renewable Resource Markets." *Rev. Econ. Stud.* 51(1984):289–303.

Rausser, G. C. "Active Learning, Control Theory, and Agricultural Policy." *Amer. J. Agr. Econ.* 60(1978):476–90.

Robison, L. J., and P. J. Barry. *The Competitive Firm's Response to Risk*. New York: Macmillan Co., 1987.

Rosegrant, M. W., and J. A. Roumasset. "The Effect of Fertilizer on Risk: A Heteroscedastic Production Function with Measurable Stochastic Inputs." *Aust. J. Agr. Econ.* 19(1985):107–21.

Schuss, Z. *Theory and Applications of Stochastic Differential Equations*. New York: John Wiley & Sons, 1980.

Sethi, S. P., and J. P. Lehoczky. "A Comparison of the Ito and Stratonovich Formulations of Problems in Finance." *J. Econ. Dynamics and Control* 3(1981):343–56.

Smith, C. W., Jr. "Applications of Option Pricing Analysis." *The Modern Theory of Corporate Finance*, ed. M. C. Jensen and C. W. Smith, Jr. New York: McGraw-Hill Book Co., 1984.

——. "Option Pricing: A Review." *J. Finan. Econ.* 3(1976):3–51.

SriRamaratnam, S., D. A. Bessler, M. E. Rister, J. E. Matocha, and J. Novak. "Fertilization Under Uncertainty: An Analysis Based on Producer Yield Expectations." *Amer. J. Agr. Econ.* 69(1987):349–57.

Stefanou, S. E. "Technical Change, Uncertainty, and Investment." *Amer. J. Agr. Econ.* 69(1987):158–65.

Stratonovich, R. L. "A New Representation for Stochastic Integrals and Equations." *SIAM J. Control* 4(1966):362–71.

Taylor, C. R. "Stochastic Dynamic Duality: Theory and Empirical Applicability." *Amer. J. Agr. Econ.* 66(1984):351–57.

Taylor, C. R., and O. R. Burt. "Near-Optimal Management Strategies for Controlling Wild Oats in Spring Wheat." *Amer. J. Agr. Econ.* 66(1984):50–60.

Taylor, C. R., and J.-P. Chavas. "Estimation and Optimal Control of an Uncertain Production Process." *Amer. J. Agr. Econ.* 62(1980):675–80.

Taylor, C. R., and H. Talpaz. "Approximately Optimal Carryover Levels for Wheat in the United States." *Amer. J. Agr. Econ.* 61(1979):32–40.

Thompson, S. R., and G. E. Bond. "Off-Shore Commodity Hedging Under Floating Exchange Rates." *Amer. J. Agr. Econ.* 69(1987):46–55.

Wong, E., and M. Zakai. "On the Relation Between Ordinary and Stochastic Differential Equations." *Int. J. Eng. Sci.* 3(1965):213–29.

Zacharias, T. P., and A. H. Grube. "Integrated Pest Management Strategies for Approximately Optimal Control of Corn Rootworm and Soybean Cyst Nematode." *Amer. J. Agr. Econ.* 68(1986):704–15.

Zavaleta, L. R., R. D. Lacewell, and C. R. Taylor. "Open-Loop Stochastic Control of Grain Sorghum Irrigation Levels and Timing." *Amer. J. Agr. Econ.* 62 (1980):785–92.

Appendix 1

Synopsis of the Literature

Ito stochastic processes are the foundation of most modern mathematics literature on stochastic control. Mathematics texts are usually inaccessible to economists. Exceptions are Arnold, Horsthemke and Lefever, Fleming and Rishel, Schuss, Karlin and Taylor, and Feller (1968, 1971). In the economics literature, Ito processes were first used to study finance. Famous examples are Black and Scholes' option pricing formula and Merton's (1971, 1973a) portfolio rules and capital-asset-pricing model. Merton (1975) was among the first to use Ito control in the study of growth theory under risk and was followed by others, including Chang. Pindyck (1980, 1981, 1984), in particular, introduced Ito control into the natural resources literature. Pindyck (1982) also introduced Ito control into the adjustment cost literature and was followed by Abel and by Stefanou. Review articles by Smith (1976, 1984) and Malliaris give an overview of Ito control in finance. Anderson and Sutinen review the literature for marine economics. Chow reviews the literature for finance and natural resources. The book by Malliaris and Brock is an in-depth survey of stochastic control in finance and general economics. The book by Mangel contains original work in natural resources. And the book by Merton (1990) summarizes the work of pioneers in finance.

In agricultural economics, dynamic decisions under risk have been studied by various methods. Burt, Koo, and Dudley; Taylor and Burt; Zacharias and Grube; and McGuckin et al. either solved stochastic dynamic programming problems in discrete time or approximated the solutions. Karp and Pope solved a stochastic dynamic programming problem by linear programming. Taylor and Talpaz applied certainty-equivalence rules. Karp as well as Dixon and Howitt solved linear-quadratic-gaussian control problems. So-called dual or adaptive control in which estimates of the model are updated as decisions are made was introduced into the agricultural economics literature by Rausser and applied by Taylor and Chavas and by Zavaleta et al. Antle and Hatchett estimated a sequential decision process. And the book by Kennedy applies dynamic programming to agricultural and natural resource economics.

Appendix 2

Vector Differentiation and Control

Ito differentiation and control with a vector of state variables are no different in interpretation but much more detailed.

Vector differentiation. Let the dimensions of S be $m \times 1$, δ be $m \times 1$, σ be $m \times n$, and dZ be $n \times 1$. The vector formula corresponding to equation (4) differentiates the scalar X with respect to the vector S, where $X = f(t, S)$.

$$\text{(A4)}\quad dX = f_t dt + \sum_{i=1}^{m} f_{S_i} dS_i + 1/2 \sum_{i=1}^{m}\sum_{j=1}^{m} f_{S_iS_j} dS_i dS_j$$

$$= \left[f_t + \sum_{i=1}^{m} f_{S_i}(\delta)_i + 1/2 \sum_{i=1}^{m}\sum_{j=1}^{m} f_{S_iS_j}(\sigma\Omega\sigma')_{ij}\right]dt + \sum_{i=1}^{m} f_{S_i}(\sigma dZ)_i.$$

S_i is the ith element of the S vector and f_{S_i} and $f_{S_iS_j}$ are first and second partial derivatives of f with respect to elements of the S vector. The notation $(\delta)_i$ denotes the ith element of the δ vector; $(\sigma\Omega\sigma')_{ij}$ denotes the ijth element of the $m \times m$ covariance matrix; and $(\sigma dZ)_i$ denotes the ith element of the $m \times 1$ stochastic vector.

Vector control. The Hamilton-Jacobi-Bellman equation for a vector of state variables corresponds to equation (7):

$$\text{(A7)}\quad 0 = J_t + \underset{c}{\text{Max}}\,\{e^{-rt}U + \sum_{i=1}^{m} J_{S_i}(\delta)_i + 1/2 \sum_{i=1}^{m}\sum_{j=1}^{m} J_{S_iS_j}(\sigma\Omega\sigma')_{ij}\},$$

where J_{S_i} and $J_{S_iS_j}$ are partial derivatives of J with respect to elements of the S vector.

Optimality conditions when there is a vector of state variables are not widely available in the literature. The proof is tedious but it can be shown that the optimality condition for the controls is

$$\text{(A8)}\quad 0 = e^{-rt}U_c + \sum_{i=1}^{m} J_{S_i}(\delta_c)_i + \sum_{i=1}^{m}\left[\sum_{j=1}^{m} J_{S_iS_j}(\sigma\Omega)_{j1}; \ldots ; \sum_{j=1}^{m} J_{S_iS_j}(\sigma\Omega)_{jn}\right](\sigma'_c)_i\,;$$

U_c is the partial derivative of utility with respect to control, c, and $(\delta_c)_i$ is the partial derivative of the ith element of δ. The term in square brackets is a $1 \times n$ vector written out explicitly. The notations $(\sigma\Omega)_{j1}$ and $(\sigma\Omega)_{jn}$ denote the j1st and the jnth elements of the $m \times n$ $\sigma\Omega$ matrix. $(\sigma'_c)_i$ is the partial derivative of the ith column of the $n \times m$ matrix, σ'.

The marginal utility of a state is the shadow price or costate variable. Costates can be important in analyzing a theory, particularly when there is a vector of states and, hence, a vector of costate variables. It can be shown that the Ito differential equation for costate dJ_{Sk}, corresponding to state S_k, $k = 1, \ldots, m$, is

$$\text{(A9)}\quad dJ_{Sk} = -\left[e^{-rt}U_{Sk} + \sum_{i=1}^{m} J_{S_i}(\delta_{Sk})_i + \sum_{i=1}^{m}\left[\sum_{j=1}^{m} J_{S_iS_j}(\sigma\Omega)_{j1}; \ldots ; \sum_{j=1}^{m} J_{S_iS_j}(\sigma\Omega)_{jn}\right](\sigma'_{Sk})_i\right]dt + \sum_{i=1}^{m} J_{SkS_i}(\sigma dZ)_i\,;$$

U_{Sk}, δ_{Sk}, and σ'_{Sk} are derivatives with respect to S_k.

Setting m equal to one in equations (A7), (A8), and (A9) gives the scalar case discussed in equations (7) and (8).

Appendix 3

Stochastic Wealth

A farmer will have inventories of risky assets, A_i, valued at prices, p_i, and, perhaps, a risk-free bond, B, valued at p_w. Liabilities are negative assets. A farmer's wealth is the value of assets and liabilities summed:

$$W = \sum_i p_i A_i + p_w B.$$

Wealth is stochastic because assets and prices are. Decisions are made at time t, and the outcomes are revealed at time $t + dt$. Ito differentiates wealth using equation (A4) in appendix 2:

$$dW = \sum_i dp_i A_i + dp_w B + \sum_i [p_i + dp_i]dA_i + [p_w + dp_w]dB.$$

The first two terms are capital gains on beginning inventories. The last two terms are additions to inventories valued at ending prices. At the beginning of each time period, the farmer forms expectations about ending prices. It is typ-

ical in the finance literature to assume price expectations are log-normally distributed:

$$dp_i/p_i = [\delta_i + \sigma_i\epsilon_i]dt = \delta_i dt + \sigma_i dz_i;$$

$$dp_w/p_w = \delta_w dt;$$

δ denotes an expected rate of appreciation or depreciation, σ is the standard deviation of the forecast, ϵ is normally distributed white noise and dz is a Weiner process. Price expectations may be correlated across risky assets. Given these expectations, the farmer chooses a portfolio. Once the A_i's are known, B is determined by the wealth constraint.

$$B = \left[W - \sum_i p_i A_i\right]/p_w.$$

In addition to appreciating or depreciating in value, inventories may be acquired or be degraded:

$$\begin{aligned} dA_i &= [a_i - g_i(A, c) - s_i(A, c)e_i]dt \\ &= [a_i - g_i(A, c)]dt - s_i(A, c)dZ_i. \end{aligned}$$

Acquisitions are a_i. The rate of degradation, g_i, is predicted with error $s_i e_i$, where s is a standard deviation, e is white noise, and dZ is a Weiner process. Stochastic degradation may be correlated across inventories, but assume there is no correlation with prices. By definition, acquisitions of risky assets and purchases of risk-free bonds must be financed from production income above variable costs, called gross margin, π, after consumption expenditures, $p_q q$, have been subtracted. The portion, w, of wealth accumulated from the gross margin above consumption expenditures is a stochastic integral over time.

$$w(t, \pi) = \int_0^t (\pi - p_q q)ds.$$

Ito differentiates this contribution to wealth using equation (4) and equates the result to the value of risky asset acquisitions plus risk-free bond purchases:

$$\sum_i [p_i + dp_i]a_i dt + [p_w + dp_w]dB = \pi dt + d\pi - p_q q dt.$$

Finally, substitute price expectations, the wealth constraint for risk-free bonds, inventory expectations, and the financing of assets and bonds into the change in wealth:

$$\begin{aligned} dW = \Bigg[\delta_w W + \sum_i (\delta_i - \delta_w)p_i A_i - \sum_i p_i g_i(A, c) + \pi \\ - p_q q\Bigg]dt + \sum_i p_i A_i \sigma_i dz_i - \sum_i p_i s_i(A, c)dZ_i + d\pi. \end{aligned}$$

This is equation (10). Maximizing expected utility subject to this single equation is equivalent to maximizing expected utility subject to multiple equations for wealth, assets, and prices. In a model with multiple equations, the asset and price equations are as given previously and the wealth equation would be

$$dW = \left[\delta_w\left[W - \sum_i p_i A_i\right] - \sum_i p_i a_i + \pi - p_q q\right]dt + d\pi.$$

Verifying that the two models give the same answer requires patience, vector control techniques from appendix 2, and the identities, $J_{Ai} = J_W[\partial W/\partial A_i] = J_W p_i$ and $J_{pi} = J_W[\partial W/\partial p_i] = J_W A_i$.

Causality between Dairy Farm Size and Productivity

Alfons Weersink and Loren W. Tauer

The direction of causality between dairy farm size and productivity is examined for each state using multivariate Granger-causality tests. The results only partially support the view that technological change has caused increases in dairy farm size. The direction of causality appears to be more from size to productivity. Changes in productivity and average herd size appear driven by price changes.

Key words: dairy, farm size, multivariate Granger causality, productivity.

The decrease in dairy farm numbers is often assumed to result from technological advances, permitting more output to be produced from available inputs (Cochrane). Others suggest low adoption of dairy technological advances in a region may reflect the large number of small farms in that region (Jesse). The question then becomes whether increases in productivity stemming from technological progress result in fewer but larger farms, or whether larger farms result in more technology use with greater productivity. Or, is there a feedback between productivity and farm size, or vice versa? Confounding this issue is evidence that reductions in farm numbers and increases in average farm size are the result more of changes in relative factor prices than of technological change (Kislev and Peterson). Others contend that technology adoption is determined more by relative prices, including returns available from alternative enterprises and general economic conditions than farm size (Ruttan, Buxton).

The alternative hypotheses on the direction of causality between farm size and productivity have quite different policy implications. If productivity increases lead to larger farms, then research priorities should be shifted if small farms are preferred to large operations. On the other hand, if no causal effect is determined from productivity to farm size, then current research in dairy farming should continue to allow farmers to be as productive, and therefore as competitive, as possible. If the reverse causality from farm size to productivity exists, then technological advance requires larger farms. This relationship suggests a continued trend toward larger farms because increased size leads to subsequent productivity increases. Perhaps no causal effect between farm size and productivity exists. Instead, both may be affected by price changes, implying that control of market forces could alter the direction and rate of change for both farm size and productivity levels.

The purpose of this paper is to determine which variables have a causal effect on productivity in the dairy industry and on average dairy farm size, with special emphasis on the causal relationship between productivity and farm size. Dairy farm size is measured as the average number of dairy cows per farm. Productivity is measured as milk production per cow. Although this single input productivity measure may be biased, it is the most accurate single input measure available given the lack of data on other inputs, such as labor and capital, specific to dairy farming available at the state level.

The analysis is conducted on a state basis for all forty-eight continental states, given the regional diversity in dairy technologies and economic conditions within the United States. The direction of causality is determined for each state using a refinement of the Granger causality test procedures which included structural and explanatory variables in the estimation. The next sections describe the multivariate approach used followed by the data, results, and conclusions.

The authors are, respectively, an assistant professor, Department of Agricultural Economics and Business, University of Guelph, and an associate professor, Department of Agricultural Economics, Cornell University.

The authors thank E. Jesse, B. F. Stanton, C. G. Turvey, and two anonymous *Journal* referees for their helpful comments.

Method and Data

Causality, as developed by Granger, is defined in terms of a predictability criterion. A variable X causes another variable Y for a given information set which includes both X and Y if prediction of the current value of Y is improved by using past values of X rather than by not doing so (Pierce and Haugh). Instantaneous causality occurs if the current value of X in addition to its past values helps in the prediction of Y. By interchanging the roles of X and Y, reverse causality as well as the existence of feedback between the two variables can be examined.

Empirical testing of Granger causality involves regressing a variable (Y) on lagged values of itself and on lagged values of the other variable of interest (X). It is assumed that the process generating (Y, X) can be expressed as an infinite order autoregression (Granger and Newbold). However, the Granger test involves truncating the order of the process and fitting the following model

$$(1)\quad Y_t = \alpha + \sum_{i=1}^{K} B_i Y_{t-i} + \sum_{j=1}^{L} \lambda_j X_{t-j} + \varepsilon_t,$$

where α is the intercept, K and L are the order of autoregression for the variables Y and X, respectively, B_i is the parameter associated with the ith lag of variable Y, λ_j is the parameter associated with the jth lag of variable X, and ϵ_t is white noise. The assumption on the error term requires that variables are stationary or that the presence of serial correlation has been removed through a filtering process. The null hypothesis that X does not Granger cause Y is determined by comparing the F-test of this full model [equation (1)] versus a restricted model in which Y is regressed on only its own lagged values ($\lambda_j = 0, j = 1, 2, \ldots, L$).

An alternative causal test by Sims is based on a regression of Y on past and future actual values of X. A causal relationship is established from X to Y if the subset of parameters associated with the future values of X are not significantly different from zero. A variation of the Sims approach proposed by Geweke, Meese, and Dent involves estimating equation (1) but with future values of X also included.

A third procedure suggested by Pierce and Haugh involves times-series methods. An integrated autoregressive-moving average model (ARIMA) is fitted for each variable. The test for causality between X and Y is based on the significance of the cross-correlation functions of the error terms for each time series. A variant of this time-series approach, also suggested by Pierce and Haugh, is based on Box-Jenkin's dynamic regression models, or transfer functions. This test procedure involves estimating the transfer function and then examining the X statistic formed for negative lags to determine if unidirectional causality or feedback exits.

These three causal test procedures have been shown to be theoretically indistinguishable by Pierce and Haugh and by Fiege and Pearce. Despite their theoretical equivalence, Conway et al. and Fiege and Pearce have shown that inconsistent conclusions may result from the various tests due to the choice of lag length, correlation between regressors, serial correlation, or power of the test statistic used (Gupta 1988). Simulation results by Geweke, Meese, and Dent and by Nelson and Schwert, however, both indicated a preference for the Granger and Sims test over the Haugh-Pierce test.

A major criticism of these causal tests arises from their lack of structure which economic theory suggests should be incorporated. The majority of causality tests have been bivariate models. The omission of relevant explanatory variables has been shown to result in uninterpretable test conclusions (Jacob, Leamer, and Ward). According to Cooley and LeRoy, such nonstructural models may be only summarizing correlations rather than determining causality. Before a causal relationship can be established, Zellner states that subject matter must be incorporated into any causal law to yield reasonable predictions of future data.

In order to mitigate the lack of the theoretical structure in the majority of causality test procedures the causality test of Darrat is utilized here. It is a variant of the Granger test procedure, which has been shown, by Geweke, Meese, and Dent, and by Nelson and Schwert through a simulation analysis, to perform better than the time-series methods. The test is cast in a multivariate framework in order to include additional influential variables suggested by theory and avoid specification error.[1] In addition, the lag length is chosen using Akaike's minimum final prediction error (FPE), which was shown by Thornton and Battan to perform well in the selection of an appropriate lag structure in comparison to other statistical criteria. Thus, Dar-

[1] The Box-Jenkin's transfer function models can also be made consistent with theory by incorporating additional variables of importance into the test procedure. See Gupta (1987 and 1988) for examples.

rat's approach imposes some structure on the model by including other possible influential variables as suggested by theory and by testing for lag length with a valid statistical test.

The dependent variables in this study were average dairy farm size and average production per cow at the state level. Farm size is measured as the average number of dairy cows per farm and was constructed by dividing the total number of milk cows by the number of farm operations with milk cows. These variables and average milk yield were obtained from *Milk: Production, Disposition and Income* by state from 1964 through 1987. Average milk yield is acknowledged to be a partial productivity measure which is affected by both the adoption of new technology and by input adjustments due to price changes. However, a total factor productivity measure cannot be constructed for each observation given the poor measures of input usage in the dairy sector for each state for each time period. In contrast, milk production per cow is constructed from monthly surveys of dairy farmers for each state and is therefore the most accurate single input productivity measure.

The explanatory factors assumed to influence size and productivity on an individual farm are prices. The state all milk price is also from *Milk: Production, Disposition and Income*. Dairy concentrate price is from *Milk Production;* the dairy cow purchase price was obtained from *Agricultural Prices;* and the wage rate, estimated by the wages paid to all farm hired labor, was obtained from *Agricultural Statistics*. A proxy for the returns of an alternative enterprise is the weighted average price for beef cows sold for breeding, feeding, or slaughter and dairy cattle sold for slaughter as provided by *Agricultural Prices*. The slaughter price is also a determinant in the culling decision. General economic conditions was proxied by the unemployment rate obtained from the *Handbook of Labor Statistics*.

The first step in the Darrat test procedure was to transform the two dependent variables, average herd size, and average productivity levels, plus the seven explanatory variables into a stationary covariance process. Stationarity is necessary to ensure that the causal effect is not improperly attributed to serial correlation. This was done by expressing the variables in logs and differencing until each variable was stationary. A variable was deemed stationary if, when regressed against time and an intercept, the coefficient on time was not significantly different from zero. Single differencing was sufficient to obtain stationarity for the majority of variables. However, milk price and wage rate had to be differenced twice in 30% and 20% of the states, respectively.

The next step was to regress each of the two dependent variables, average herd size, and average productivity levels (milk production per cow), against its own lagged values with the length of lag chosen by the minimum *FPE*. The *FPE* value for an order of lag h is

$$(2)\quad FPE(h) = [(T + h + 1)/(T - h - 1)] \cdot RSS(h)/T,$$

where T is the number of observations and *RSS* is the sum of the residual sum of squares. Only a single lag length ($h^* = 1$) was necessary for both dependent variables.

Bivariate regressions were then estimated for each of the dependent variables with its lagged value and the lags of each of the other explanatory variables considered separately. The appropriate lag length for each explanatory variable (k) in the farm size and productivity bivariate equations was determined by minimizing a modified *FPE*;

$$(3)\quad FPE(h^*, k) = [(T + h^* + k + 1)/(T - h^* - k - 1)] \cdot RSS(h^*, k)/T.$$

Trivariate regressions were then estimated, consisting of the lagged dependent variable, the explanatory variable with the minimum *FPE* as determined in the previous step and its appropriate lag, and the lags of the remaining explanatory variables considered separately. The modified *FPE* criterion in (3) was again used to determine the appropriate lag length for each variable and the variable with the lowest *FPE* was added along with its appropriate lag to the regression equation. Each of the remaining explanatory variables was subsequently added following the same process until all the variables were included in each of the two equations.

Using milk production per cow in Montana as an example, the initial bivariate regression found milk price with no lags to have the lowest *FPE* value. Milk yield was then regressed against its lagged value, milk price, and lags of the other variables, to determine the appropriate lag length for each of these variables and the associated *FPE* value calculated. Herd size was then added to the regression based on this criterion and the process repeated. In the next step, cow price had the minimum *FPE*, so it along with its lagged value was added to the regression and the steps repeated until all variables were included.

Generally, the variables chosen to enter first

were found later to have a Granger causal relationship with the dependent variables, while those that entered later did not. The appropriate lag length for each of the additional variables was again determined by the *FPE* procedure. A single lag was the most required for any variable in each state. However, the decision to lag or not as indicated by the *FPE* value varied considerably among variables and states. The result was a multivariate equation for each of the dependent variables, average farm size and milk yield, with the ordering and lag length for each of the explanatory variables calculated with Akaike's final prediction error criterion.

The equations for average farm size and milk yield, estimated separately for each state using OLS, were then combined to form a two-equation system. Since error terms across equations are likely to be correlated, seemingly unrelated regression (SUR) was used to estimate the system. Granger tests of causality were inferred for each variable by comparing the F-test computed from the full model and reduced version in which the variable of concern was excluded from the appropriate equation.

Results

The causal test results for individual states grouped by region are listed in tables 1 and 2. These tables show the F-values computed from the full two-equation model with all explanatory variables included and the reduced model in which the variable of concern is excluded from the equation of the dependent variable for which causality is being determined. The F-values determine whether the variables listed horizontally have a causal effect on average milk production per cow (table 1) or average herd size (table 2). An F-value above the critical value indicates rejection of the null hypothesis that the listed variables does not affect average production per cow or average herd size. Rejection of the null hypothesis implies acceptance of the alternative hypothesis that the listed variable does have a causal influence.

It appears, (given the large F-values in the first column of table 1), that larger average herd size does cause higher average milk production per cow in the majority of states in the Southeast, Delta, Mountain, and Pacific regions, and for the two largest milk producing states in the Northeast along with Connecticut and Maryland. These states have experienced relatively large increases in milk yield, and it appears that larger average size farms were partly responsible. This suggests the existence and exploitation of size economies by larger farms in those states. Average milk production per cow does not appear to be affected by herd size in the majority of states outside of the regions in the southern and western parts of the country. This result supports the findings of Jesse, who found no relationship between production per cow and farm size for herds greater than fifty cows in Wisconsin. The intensive housing requirements in most of the northern United States limit economies of size relative to the warmer regions. Jesse also indicates that reliance on home grown feeds requires extensive management requirements that may not be available on mostly family-based operations in these northern regions.

Although larger farms may lead to greater production per cow in many states, indicating that much technological advance required larger farms, there is less evidence that the opposite is true; that greater production per cow leads to larger average farm sizes (table 2). However, the states where milk production per cow does cause larger herd size are generally also states where larger herd size also causes higher milk production per cow (New York, Pennsylvania, Georgia, Arkansas, Wyoming, Arizona, Montana, and Oregon). Some of the new technology introduced during this period of time, such as milking parlors, often required increased herd size, which in turn increased production per cow.

The multivariate approach for causality testing allowed the examination of additional factors affecting milk production per cow and farm size. Milk price does not appear to affect milk production per cow except in some states in the Corn Belt and mountain areas, or states bordering the Corn Belt, such as Wisconsin, Nebraska, and Kentucky. Dahlgran found that these regions have higher own-price milk supply elasticities. Milk price also affects production per cow in New Hampshire and New Jersey. Milk price causes changes in farm size in only a few states, mostly located in the mountain region.

Cow prices have a causal effect on milk yield in many states, especially in the Northeast. In contrast, cow prices have an impact on average herd size in only a few states. One would expect higher-producing cows to have higher values, but it also appears that high cow prices encourage farmers in some states to adopt technologies to further increase the productivity of those cows. An example is a better feeding program. In contrast, higher cow prices do not encourage larger farms.

Table 1. Multivariate Causality Test of Average Milk Production per Cow by State

	Average Milk Production per Cow Is Not Granger Caused by						
Region	Herd Size	Milk Price	Cow Price	Feed Price	Beef Price	Wage Rate	UE Rate
Northeast							
Connecticut	5.29**[a]	0.14	0.78	4.66**	1.12	1.21	0.09
Delaware	1.62	0.21	0.76	1.19	0.08	0.20	0.58
Maine	0.65	0.11	2.59*	3.21	1.84	0.12	0.17
Maryland	5.41**	0.59	10.07**	3.37*	8.98**	0.01	0.02
Massachusetts	0.21	0.35	2.85	2.74	1.56	0.57	0.06
New Hampshire	0.22	6.56**	11.61**	1.16	3.75**	7.02**	11.73**
New Jersey	0.83	5.12**	4.61**	6.24**	9.13**	0.52	0.01
New York	4.35**	0.25	0.22	0.63	0.12	2.73	0.49
Pennsylvania	5.11**	1.36	8.13**	4.41**	3.29*	0.29	0.34
Rhode Island	0.02	1.50	0.08	3.68**	1.14	1.40	1.16
Vermont	1.12	0.19	1.82	9.94**	0.07	0.38	1.46
Lake							
Michigan	0.04	1.60	2.07	2.91	0.03	0.24	3.05
Minnesota	0.55	0.77	1.35	0.02	0.03	0.24	3.05
Wisconsin	1.38	4.27**	29.53**	3.68*	21.63**	0.22	2.01
Corn Belt							
Illinois	0.15	3.24*	0.02	0.36	2.96	0.07	1.04
Indiana	0.34	2.41	0.12	5.69**	0.02	0.08	0.28
Iowa	0.58	1.66	1.25	3.21*	1.44	6.51**	0.80
Missouri	0.94	2.86	0.26	0.03	0.54	0.94	0.27
Ohio	0.33	3.96*	0.01	3.05*	0.14	0.08	0.29
Northern Plains							
Kansas	0.03	0.53	0.35	1.05	0.01	0.86	0.68
Nebraska	2.66	4.27**	2.37	0.02	0.82	1.66	1.94
North Dakota	0.24	0.11	0.25	0.06	0.04	1.24	4.07**
South Dakota	1.33	0.02	0.07	0.52	0.23	0.11	2.56
Appalachian							
Kentucky	0.57	4.81**	5.03**	4.79**	11.08**	4.06**	1.67
North Carolina	0.04	1.19	0.08	3.53*	5.19**	3.61*	0.92
Tennessee	0.55	0.54	0.11	0.54	0.02	0.79	1.44
Virginia	1.66	1.99	0.08	8.02**	0.83	2.57*	3.06**
West Virginia	1.42	0.08	1.79	5.98**	0.01	2.73*	1.12
Southeast							
Alabama	3.74*	1.92	7.51**	3.63**	1.33	0.25	0.24
Florida	0.95	0.67	0.83	0.91	1.37	2.50	1.78
Georgia	3.78**	0.19	0.39	0.11	0.01	0.79	1.54
South Carolina	0.20	2.19	0.01	1.31	5.21**	0.72	2.15
Delta							
Arkansas	5.42**	0.05	3.08**	0.78	1.61	0.45	2.27
Louisiana	3.4**	0.12	2.69*	2.43	2.71*	1.58	1.45
Mississippi	7.08**	0.07	2.84*	0.57	0.09	0.41	3.25**
Southern Plains							
Oklahoma	0.01	0.16	0.24	0.52	0.73	0.17	1.12
Texas	1.24	0.05	0.01	0.12	0.59	1.12	0.65
Mountain							
Arizona	2.81*	2.90*	0.56	1.37	0.75	2.87*	3.16*
Colorado	0.53	0.01	0.75	3.15*	2.14	1.41	1.10
Idaho	1.32	3.13*	4.17**	2.30	2.72	0.72	0.13
Montana	3.43*	3.70*	2.20	0.53	1.89	0.10	2.01
Nevada	0.01	0.67	0.85	1.60	0.19	1.79	0.02
New Mexico	3.41**	3.36*	2.40	6.77**	4.05*	0.31	0.11
Utah	0.69	0.60	1.20	0.06	0.19	1.34	0.34
Wyoming	5.51**	0.78	0.01	0.05	4.18*	1.86	2.11
Pacific							
California	3.69*	2.39	5.45**	0.79	7.58**	0.15	0.01
Oregon	3.89**	0.94	2.06	0.41	0.92	0.01	0.07
Washington	0.01	1.38	1.55	2.58*	1.71	0.38	0.82

[a] Two asterisks indicate rejection of hypothesis at a significance level of 5%; single asterisk indicates rejection of hypothesis at a significance level of 10%.

Table 2. Multivariate Causality Test of Average Herd Size by State

Region	Average Herd Size Is Not Granger Caused by						
	Milk Yield	Milk Price	Cow Price	Feed Price	Beef Price	Wage Rate	UE Rate
Northeast							
Connecticut	0.96	0.01	0.34	0.06	0.49	0.34	0.22
Delaware	0.01	3.73**[a]	0.79	0.08	3.24*	1.18	0.15
Maine	2.19	0.15	0.14	0.61	0.02	0.37	0.03
Maryland	1.80	1.35	1.85	0.30	0.53	0.02	2.50
Massachusetts	0.07	0.17	0.21	0.07	0.04	0.54	0.19
New Hampshire	0.42	2.03	0.73	0.23	0.01	2.03	1.68
New Jersey	1.83	0.02	1.57	0.05	2.54	0.78	2.21
New York	4.00**	0.78	0.77	0.01	0.06	9.37**	5.69**
Pennsylvania	6.66**	5.61**	3.99**	0.43	1.09	1.19	1.28
Rhode Island	1.41	0.63	0.05	1.22	0.37	0.48	4.89**
Vermont	0.11	0.32	0.03	1.51	0.02	0.23	3.31*
Lake							
Michigan	0.06	0.57	0.87	0.03	0.47	0.29	0.02
Minnesota	0.53	0.01	0.31	0.01	0.03	0.01	0.08
Wisconsin	0.03	0.12	1.55	0.08	1.68	1.14	2.24
Corn Belt							
Illinois	0.59	0.01	2.57	3.56*	1.27	0.37	0.02
Indiana	0.17	0.02	0.04	3.38*	0.02	0.67	0.15
Iowa	0.01	1.80	0.17	4.17**	0.01	0.26	0.05
Missouri	0.56	0.01	1.70	3.03*	2.31	0.62	2.09
Ohio	1.23	0.09	0.03	2.01	3.61**	0.16	4.39**
Northern Plains							
Kansas	0.96	0.49	2.63	0.11	0.86	0.63	0.49
Nebraska	1.39	0.91	2.07	0.05	0.02	0.03	6.97**
North Dakota	1.51	3.32*	2.62*	1.69	3.37*	1.72	2.41
South Dakota	0.29	0.08	3.46*	1.93	1.92	0.70	1.37
Appalachian							
Kentucky	0.49	2.38	0.08	1.76	5.19**	3.61*	0.92
North Carolina	2.94*	0.82	0.56	1.31	0.08	3.35**	0.04
Tennessee	1.16	1.75	0.03	0.98	0.57	0.01	5.22**
Virginia	0.52	1.72	3.51*	1.91	0.49	2.62*	0.42
West Virginia	2.56	0.11	0.62	1.66	0.32	1.18	0.67
Southeast							
Alabama	0.11	1.74	0.12	1.21	0.78	0.24	1.83
Florida	2.01	1.05	2.69	0.17	0.37	2.33	0.13
Georgia	5.11**	4.81**	1.63	1.41	1.84	0.98	5.77**
South Carolina	2.81**	0.43	5.09**	3.63**	10.0**	4.82**	3.43*
Delta							
Arkansas	7.39**	0.01	0.78	0.69	0.35	0.05	0.05
Louisiana	0.35	0.85	0.99	1.98	2.87*	0.95	2.96
Mississippi	1.17	0.34	0.18	0.07	0.76	0.49	0.08
Southern Plains							
Oklahoma	1.89	1.81	1.01	1.90	2.71	2.09	4.73**
Texas	1.32	0.31	0.22	0.25	1.06	5.18**	0.32
Mountain							
Arizona	3.53**	8.42**	1.09	3.88**	3.83**	0.59	3.58*
Colorado	0.29	3.49*	1.66	0.25	1.52	3.02*	1.62
Idaho	1.21	6.03**	0.01	4.5**	4.80**	4.97**	2.96*
Montana	3.08*	0.21	0.95	1.29	0.77	1.01	1.12
Nevada	0.20	0.21	0.13	0.85	1.03	6.90**	1.93
New Mexico	0.19	6.08**	0.96	0.47	6.01**	4.42	1.08
Utah	0.01	0.01	0.01	0.22	0.19	1.60	1.87
Wyoming	5.08**	1.80	3.52**	3.82**	0.14	0.55	0.63
Pacific							
California	1.50	0.13	2.83*	3.13*	5.04**	0.39	2.87*
Oregon	3.81*	0.76	0.18	1.53	5.23**	0.22	1.01
Washington	0.41	0.66	0.48	2.79*	2.62	4.2**	4.56**

[a] Double asterisk indicates rejection of hypothesis at a significance level of 5%; single asterisk indicates rejection of hypothesis at a significance level of 10%.

Feed price had a significant impact on average milk yield in many states, especially in the Northeast and the Appalachia, two feed deficit areas. High feed prices reduce feed concentrate usage, which reduces milk production per cow. Feed prices cause changes in average herd size in states mostly in the Corn Belt, mountain, and Pacific regions. A high feed price means high crop prices, which may have encouraged small dairy farmers in the Corn Belt to sell their herds and specialize in crop production, leaving milk production to larger dairy farms and increasing the average size of dairy farms. In the West, high feed prices may have given larger farms a comparative advantage in purchasing and utilizing this input.

Although beef price changes do cause changes in milk production per cow for some states, no regional or other apparent pattern emerges. Beef price causes larger dairy herd sizes in states in the western regions and the South, where beef cow operations are relatively prevalent. A high beef price may have encouraged small dairy farms to switch to beef cows, increasing the average size of remaining dairy farms.

The wage rate causes higher milk production per cow in only a few states, most of which are in the Appalachian region. The wage rate also affects average herd size in the Appalachian region. This result implies that the production technology utilized in the Appalachian region may be more dependent on labor relative to other regions because average wage rate increases were no greater in the Appalachian region.

General economic conditions as measured by the unemployment rate affects milk production per cow and herd size in only a few states, and no pattern emerges. Off-farm employment is important in U.S. agriculture, but it is apparently less so for dairy farms. Operating even a small dairy farm can be a full-time job.

The fact that no clear or incomplete regional pattern exists with some variables suggests the presence of Types I and II statistical errors. An example of Type I error in table 1 is the rejection of the null hypothesis that the wage rate has not affected average milk production in Iowa. In the other four states of the Corn Belt, that null hypothesis is not rejected. An example of a Type II error is the failure to reject the null hypothesis that the feed price has not affected average milk production in Tennessee, while that null is rejected for all other states in the Appalachian region. Thus, these results, like any statistical results, must be interpreted cautiously. This discussion was based primarily upon general patterns within regions.

Conclusions

This article explored whether productivity increases lead to larger dairy farms or whether larger dairy farms allow greater productivity, where productivity is measured by milk production per cow, and dairy farm size is measured by the average number of dairy cows per farm. Granger-causality tests were used in a multivariate approach so that many causal factors could be included.

The empirical results only partially support the view that productivity change has caused changes in average herd size. Instead, the direction of causality appears to be from herd size to technology. For the western and southern states this result suggests the existence and exploitation of size economies. This causal relation is not as strong for northern states with their integrated forage and milk production sytems. It was also shown that changes in both productivity and average herd size are largely brought about by price changes, supporting the findings of Kislev and Peterson.

An important policy implication is that agricultural research in dairy farming may not lead to larger dairy farms. Instead, economic factors (prices of inputs and output) and other forces leading to structural changes may lead to larger dairy farms which are then in a position to adopt the new technology. To advocates of small farms this distinction may be moot, akin to asking what came first; the chicken or the egg. Yet, the distinction is important. If large dairy farms are to be the rule, why not provide them with the technology necessary to increase their productivity? Instead of productivity increases brought about through research, the major determinant of changes in dairy farm structure may be dairy price policy.

[Received May 1990; final revision received January 1991.]

References

Buxton, Boyd M. "Factors Affecting U.S. Milk Production." Washington DC: U.S. Department of Agricul-

ture, Econ. Res. Serv. Agr. Econ. Rep. No. 527, March 1985.

Cochrane, Willard W. *The City Man's Guide to the Farm Problem*. Minneapolis: University of Minnesota Press, 1965.

Conway, Roger K., P. A. V. B. Swamy, John F. Yanagida, and Peter von zur Muehlen. "The Impossibility of Causality Testing." *Agr. Econ. Res.* 36(1984):1–19.

Cooley, Thomas F., and Stephen F. Leroy. "Atheoretical Macroeconomics: A Critique." *J. Monetary Econ.* (1985):283–308.

Dahlgran, R. A. "Welfare Costs and Interregional Income Transfers Due to Regulation of U.S. Dairy Markets." *Amer. J. Agr. Econ.* 62(1980):288–96.

Darrat, Ali F. "Have Large Budget Deficits Caused Rising Trade Deficits?" *S. Econ. J.* 54(1988):879–87.

Fiege, Edgar L., and Douglas K. Pearce. "The Causal Relationship Between Money and Income: Some Caveats for Time Series Analysis." *Rev. Econ. and Statist.* 61(1979):521–33.

Geweke, John, Richard Meese, and Warren Dent. "Comparing Alternative Tests of Causality in Temporal Systems." *J. Econometrics* 21(1983):161–94.

Granger, Clive W. J. "Investigating Causal Relationships by Econometric Models and Cross-Spectral Methods." *Econometrica* 37(1969):424–38.

Granger, Clive W. J., and Paul Newbold. *Forecasting Economic Time Series*. New York: Academic Press, 1986.

Gupta, Satyadeo. "Profits, Investment, and Causality: An Examination of Alternative Paradigms." *S. Econ. J.* 55(1988):9–20.

——. "Testing Causality: Some Caveats and a Suggestion." *Int. J. Forecast.* 3(1987):195–209.

Jacobs, R. L., E. E. Leamer, and W. M. P. Ward. "Difficulties with Testing for Causation." *Econ. Inquiry* 17(1979):401–13.

Jesse, E. *The Relationship between Milk Production Per Cow and Herd Size in Wisconsin*. University of Wisconsin Marketing and Policy Briefing Pap. No. 15, 1987.

Kislev, Yoav, and Willis Peterson. "Process, Technology, and Farm Size." *J. Polit. Econ.* 90(1982):578–95.

Nelson, C. R., and G. W. Schwert. "Test for Predictive Relationships Between Time-Series Variables: A Monte Carlo Investigation." *J. Amer. Statist. Assoc.* 77(1982):11–18.

Pierce, David A., and Larry D. Haugh. "Causality in Temporal Systems: Characterization and a Survey." *J. Econometrics* 5(1977):265–93.

Sims, Christopher A. "Money, Income, and Causality." *Amer. Econ. Rev.* 62(1972):540–52.

Thornton, Daniel L., and Dallas S. Battan. "Lag-Length Selection and Tests of Granger Causality between Money and Income." *J. Money, Credit, and Banking* 17(1985):164–78.

U.S. Congress, Office of Technology Assessment. *Technology, Public Policy, and the Changing Structure of American Agriculture*, OTFA-F-285. Washington DC, March 1986.

U.S. Department of Agriculture. *Agricultural Prices*. Washington DC, various issues.

——. *Agricultural Statistics*. Washington DC, various issues.

U.S. Department of Agriculture, Statistical Reporting Service. *Milk Production*. Washington DC, various issues.

——. *Milk: Production, Disposition, and Income*. Washington DC, various issues.

U.S. Department of Labor, Bureau of Labor Statistics. *Handbook of Labor Statistics*. Washington DC, various issues.

Zellner, Arnold. "Causality and Causal Laws in Economics." *J. Econometrics* 39(1988):7–21.

Dual Second- and Third-Order Translog Models of Production

Paul J. Driscoll and Richard Boisvert

Monte Carlo evidence indicates that translog cost and profit models are generally incapable of accurately characterizing the underlying production technology. In order to discriminate between tracking difficulties caused by truncation of important high-order terms and errors in variable bias, Monte Carlo experiments are performed with second- and third-order cost and production models, using data generated with and without measurement error. The results suggest that it is errors in variables bias and not the translog specification, which is largely responsible for the poor tracking performances noted previously.

Key words: Monte Carlo, production and cost functions, translog.

Recently, a number of Monte Carlo experiments have evaluated the translog and other flexible form cost and profit models. These studies have focused on the relative capabilities of the various flexible forms to estimate elasticities associated with some production process (e.g., Guilkey and Lovell; Guilkey, Lovell, and Sickles; Chalfant and Gallant; Dixon, Garcia, and Anderson). The goal of many of these experiments is to identify a flexible form which closely tracks a wide array of technologies. The bleak conclusion drawn from many of these experiments is that the translog, the generalized Cobb-Douglas, the generalized Leontief, and other flexible forms are generally incapable of accurately characterizing the underlying technology.

Theoretically, one might expect flexible forms which can be interpreted as series expansions to perform well. Why, then, do flexible forms such as the translog fail to track the underlying technology? White (1980) has argued that least squares estimates of the translog flexible form coefficients may not be interpreted as Taylor series coefficients and that "reliance on the Taylor approximation interpretation is an imprecise if not totally misleading practice" (p. 163). Based on a single example, Byron and Bera refute White's findings and claim that, by using higher-order expansions, the bias associated with estimates of the Taylor-series coefficients can be reduced. To date, however, no extensive examination of this proposition has occurred.

On a related topic, Burgess, Humphrey and Moroney, and Theil have noted that elasticity estimates for a particular production process may vary markedly depending upon whether a primal (production system) or dual (cost system) approach is adopted. Burgess concluded that because flexible form production and cost functions are generally not self-dual, the divergent estimates may be attributed to the different hypotheses maintained when estimating a flexible form cost or production system. Theil and Binswanger have speculated that estimates obtained from a production system may be quite sensitive to the matrix inversions involved. Humphrey and Moroney blamed errors in variables.

These issues are explored extensively in this paper using translog flexible forms. The translog is chosen because of its popularity and because it is the focus of the White, Byron and Bera, Burgess, and Humphrey and Moroney studies. The issues are addressed using a Monte Carlo experiment; the experiment explores the performances of both second- and third-order translog expansions and both primal and dual systems over a wide range of hypothesized technologies. Third-order models are tested to determine the extent to which the exclusion of

The authors are, respectively, an assistant professor, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, and a professor, Department of Agricultural Economics, Cornell University.

This research was supported in part by Hatch Project (NY(C) 121417), U.S. Department of Agriculture.

higher-order terms from the second-order expansion affects the tracking ability of the flexible form.

Further, in order to distinguish between tracking capabilities and errors in variables bias, two schemes for generating data are employed. The first includes no measurement errors. In the second scheme, disturbances consistent with those reported by the Annual Survey of Manufacturers are added to the data. Implicit expenditure, price, and input series are created where necessary using the disturbed data in a manner consistent with procedures adopted by Burgess, Humphrey and Moroney, and Brown. That is, every attempt is made to duplicate a typical modeling exercise.

The remainder of the paper begins with an outline of the Monte Carlo experiment. Experimental results for the two cases are reported separately in the following sections and the undisturbed data case is taken up first. Finally, the major implications of the results for the design of Monte Carlo experiments and for production modeling are discussed.

The Monte Carlo Experiment

The Monte Carlo experiment has three components: (*a*) generation of the data and computation of true production characteristics, (*b*) model estimation and computation of estimated production characteristics, and (*c*) a comparison of true and estimated production characteristics.

The basic idea is to create production technologies with known characteristics, namely, elasticities of substitution and returns to scale. Inputs are generated so that their covariance is similar to agriculture and manufacturing time-series data (e.g., Berndt and Wood, Brown). Using a generalized constant elasticity of substitution (CES) production function, output levels are computed for each set of inputs. Assuming profit-maximizing behavior, a set of prices is obtained for each set of inputs. The result is a set of data rich enough to model the production technology using either a primal or dual approach. Finally, the true returns to scale and Allen partial elasticity values are calculated at each data point.

Using the generated data, parameter estimates are obtained for a variety of translog cost and production models. Estimates of returns to scale and Allen partial elasticities of substitution are computed at each data point. These estimates are compared to the true values at each data point for every replication.

Generating the Data

Two distinct error regimes are examined, the first of which includes no measurement errors in the data. With the exception of the way in which the measurement errors are introduced, the experimental design is identical for both regimes.

Fifty observations of three inputs are generated from a multivariate log-normal distribution.

$$\ln X \sim N\begin{bmatrix}0.239\\0.582\\0.391\end{bmatrix},\begin{bmatrix}0.026 & & \\ 0.039 & 0.066 & \\ 0.041 & 0.063 & 0.065\end{bmatrix}.$$

Next, output is calculated using the generalized CES production function,

$$Y_t = \left(\sum_i \delta_i x_{it}^{-\rho_i}\right)^{-1/\rho},$$

where x_{it} are inputs and Y_t is output. Seven technologies covering a broad range of possibilities (and drawn from Guilkey, Lovell, and Sickles) are synthesized with this form. Table 1 gives parameter values for the seven technologies and the average of true factor shares and Allen partials over all observations and replications.

Assuming output price is unity, input prices consistent with profit maximization are generated, and returns to scale and Allen partial elasticities of substitution are calculated.

The following steps apply only to data constructed for the second error regime. In the second regime, a fairly standard modeling problem is mimicked in which the three inputs are labor, capital, and materials. Implicit wage, capital expenditure, and material input series are created from disturbed wage bill and employment series, disturbed capital cost and capital usage series, and material price and expenditure series.[1] Details of these procedures are available from the authors.

For both data generation schemes, the last step is to calculate total cost, input expenditures, cost shares, and shares in the value of output, and to scale output, costs, inputs, and prices by their geometric means.

These steps are repeated for fifty replications of each technology. A new set of data (and disturbances, if needed) is drawn for each replication.

[1] The standard deviation of the measurement error for labor, capital, and materials is 2%, 6%, and 4% and is consistent with that reported by the Annual Survey of Manufactures (ASM) for two-digit SIC data.

Table 1. Characteristics of the Generalized CES Parameters for Seven Technologies

Technology	Parameters				Factor Shares			Allen Partial Elasticities		
	ρ	ρ_1	ρ_2	ρ_3	M_1	M_2	M_3	AES12	AES13	AES23
1	-.67	-.67	-.67	-.67	.337	.268	.395	3.030	3.030	3.030
2	2.00	2.00	2.00	2.00	.203	.402	.395	0.333	0.333	0.333
3	-.40	-.67	-.25	-.25	.609	.164	.227	1.707	1.707	1.751
4	-.55	-.30	-.50	-.70	.166	.263	.571	1.072	1.787	2.502
5	2.00	.20	2.00	3.00	.072	.462	.466	0.847	0.635	0.254
6	-1.10	-1.50	-.50	-.30	.775	.125	.100	3.609	2.578	-2.578
7	-.80	-1.10	-.50	-.40	.636	.173	.191	3.540	2.950	-0.590

Note: $\theta = 0.0$ and $\tau = 1.0$ for all technologies. M_i and AES_{ij} are averages over all replications.

Estimation Procedure

The experiment is conducted for six models, a second- and third-order translog production system model, a conventional second- and third-order translog cost system model, and a modified second- and third-order translog cost system model where the first-order condition for profit maximization is included in the system.

In the experiment, symmetry is imposed on all production system models, and symmetry and price homogeneity are imposed on all cost system models. The second-order translog production system (for output y and inputs x_i) is given by

$$(1)\qquad Y_t = \alpha_0 + \alpha' X_t + 1/2\, X_t' \beta X_t + e_{0t}$$

$$M_t^* = \partial Y_t / \partial X_t = \alpha + \beta X_t + e_t,$$

where $X_t' = (\ln x_{1t}, \ln x_{2t}, \ldots, \ln x_{mt})$, $Y_t = \ln Y_t$, $\alpha' = (\alpha_1, \alpha_2, \ldots, \alpha_m)$ and β is an $m \times m$ symmetric matrix of parameters, M_t^* is a vector of shares in the value of output, and e_t is a vector of share equation errors at time t. The third-order translog system model is given by

$$(2)\qquad Y_t = \alpha_0 + \alpha' X_t + 1/2\, X_t' \beta X_t + 1/6\, X_t'(\tau'(I \otimes X_t))X_t + e_{0t}$$

$$M_t^* = \alpha + \beta X_t + 1/2(\tau'(I \otimes X_t))X_t + e_t,$$

where τ' is an $m \times m^2$ matrix of parameters

$$\tau' = \begin{bmatrix} \tau_{111} & \cdots & \tau_{m11} & \tau_{112} & \cdots & \tau_{m12} & \cdots\cdots & \tau_{11m} & \cdots & \tau_{m1m} \\ \tau_{121} & & \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ \vdots & & \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ \tau_{1m1} & \cdots & \tau_{mm1} & \tau_{1m2} & \cdots & \tau_{mm2} & \cdots\cdots & \tau_{1mm} & \cdots & \tau_{mmm} \end{bmatrix}.$$

Here, τ' can be thought of as a three-dimensional $m \times m \times m$ symmetric matrix which, after stacking, requires only two dimensions. Symmetry requires

$$\beta_{ij} = \beta_{ji} \text{ and } \tau_{ijk} = \tau_{ikj} = \tau_{jik} = \tau_{jki} = \tau_{kij} = \tau_{kji}.$$

The second-order translog cost model (for cost C and input prices w) is

$$(3)\qquad C_t = \delta_0 + \delta' w_t + w_t' \Gamma w_t + \varepsilon_{0t}$$

$$M_t = \partial C_t / \partial w_t = \delta + \Gamma w_t + \varepsilon_t,$$

where $w_t' = (\ln w_{1t}, \ln w_{2t}, \ldots, \ln w_{mt}, \ln y_t)$, $C_t = \ln C_t$; $\delta' = (\delta_1, \delta_2, \ldots, \delta_m, \delta_y)$ and Γ is an $(m + 1) \times (m + 1)$ symmetric matrix of parameters, M_t is a vector including the cost shares

and marginal cost condition (e.g., cost elasticity of output), and ε_t is a vector of share equation errors at time t. Symmetry is imposed on Γ and price homogeneity is obtained with the constraint $\Gamma'R = 0$, where $R' = (1, 1,,,, 1, 0)$.

The symmetry and price homogeneity constraints render the mth component of M redundant. The mth share equation is dropped to avoid a singular error covariance matrix. The $m + 1$th component of M is a marginal cost condition and comes from differentiating the cost function with respect to output. If producers are profit maximizers, values for $\partial \ln C/\partial \ln Y$ may be generated and the equation may be added to the system. When the weaker hypothesis of cost minimization is maintained, marginal costs are not known, $\partial \ln C/\partial \ln Y$ may not be generated, and the $m + 1$th component of M must also be omitted.

Because profit maximization is assumed when the data are generated, it is appropriate to include the $m + 1$ component of M. In order to compare these results to those of Guilkey, Lovell, and Sickles, the standard cost system model without the marginal cost condition included is also estimated.

The third-order translog cost model is

$$(4) \quad C_t = \delta_0 + \delta' w_t + 1/2\, w_t' \Gamma w_t + 1/6\, w'_t(\Theta'(I \otimes w_t))w_t + \varepsilon_{0t}$$

$$M_t = \partial C_t/\partial w_t = \delta + \Gamma w_t + 1/2\, \Theta'(I \otimes w_t)w_t + \varepsilon_t,$$

where Θ' is an $(m + 1) \times (m + 1)$ matrix of parameters with the following characterization. Let $n = m + 1$:

$$\Theta' = \begin{bmatrix} \theta_{111} \cdots \theta_{n11} & \theta_{112} \cdots \theta_{n12} & \cdots\cdots & \theta_{11}n \cdots \theta_{n1n} \\ \theta_{121} & \vdots \quad \vdots \quad \vdots & \vdots & \vdots \quad \vdots \\ \vdots & & & \\ \theta_{1n1} \cdots \theta_{nn1} & \theta_{1n2} \cdots \theta_{nn2} & \cdots\cdots & \theta_{1nn} \cdots \theta_{nnn} \end{bmatrix}.$$

Symmetry in the third-order system requires

$$\gamma_{ij} = \gamma_{ji} \text{ and } \theta_{ijk} = \theta_{ikj} = \theta_{jki} = \theta_{jik} = \theta_{kji} = \theta_{kij}.$$

Price homogeneity requires

$$\Gamma'R = 0 \text{ and } \Theta'(I \otimes R) = 0.$$

As is the case with the second-order cost models, two third-order translog cost systems are estimated, one which includes the marginal cost condition, and one which does not.

Calculating the Production Characteristics

All models are estimated using an iterative Zellner procedure in PROC SYSNLIN(SAS).[2] Parameter estimates are used to calculate returns to scale and Allen partial elasticity estimates at each data point for each of the six models. In turn, these estimates are compared to the corresponding true values. The averages of the true values, the averages of the estimated values, and the mean of absolute deviations (MAD) between the estimated and true values for the fifty observations in the sample are retained for comparison. Good model performance is indicated by small MAD values. When the average of the estimates differs from the average of actual values and MAD is equal to this difference, the bias is unidirectional in all replications.

Monte Carlo Results

To analyze the results of these Monte Carlo experiments, it is convenient to compare the performances of (*a*) cost and production systems, (*b*) cost models which impose the profit maximization condition with cost models that do not, and (*c*) third-order expansions with those of the second-order expansions. In the commentary below, the six models are abbreviated as follows: second-order translog production system (PTWO), third-order translog production system (PTHR), second-order cost system (CTWO), third-order cost system (CTHR), second-order cost system with profit maximization imposed (C2PR), and third-order cost system with profit maximization imposed (C3PR).

Regime 1—Data Are Measured Correctly

The results of this experiment are summarized in table 2. They demonstrate that when data are measured correctly, the translog systems perform well, even on technologies which require complementary inputs. In contrast to the results of Guilkey, Lovell, and Sickles, AES estimates are essentially unbiased and MAD values are relatively small.[3] Some subtle differences in

[2] Restrictions necessary to insure concavity of the cost function were not imposed for several reasons. First, the restrictions are not necessary to achieve good estimates when the data are measured accurately, and, second, Dixon, Garcia, and Anderson found that the restrictions are not all that useful when the data are measured with error.

[3] Of course, the Guilkey, Lovell, and Sickles data contain an error component.

Table 2. Summary of Monte Carlo Results from Regime 1—Data Measured Correctly

Models[a]	Allen Partial Elasticities of Substitution AES11	AES22	AES33	AES12	AES13	AES23	Returns to Scale
				Technology 1[b]			
ACTUAL[c]	−5.973	−8.286	−4.654	3.030	3.030	3.030	1.000
PTWO SYS[c]	−6.012	−8.388	−4.673	3.060	3.045	3.055	1.000
MAD STAT[c]	0.171	0.444	0.073	0.182	0.187	0.211	0.000
PTHER SYS	−5.975	−8.288	−4.655	3.031	3.031	3.031	1.000
MAD STAT	0.006	0.009	0.005	0.005	0.003	0.005	0.000
CTWO SYS	−5.979	−8.300	−4.656	3.032	3.035	3.033	1.000
MAD STAT	0.055	0.147	0.030	0.059	0.061	0.072	0.000
CTHR SYS	−5.974	−8.286	−4.654	3.031	3.030	3.030	1.000
MAD STAT	0.003	0.007	0.003	0.003	0.002	0.004	0.000
CPR2 SYS	−5.980	−8.304	−4.655	3.035	3.033	3.033	1.000
MAD STAT	0.055	0.143	0.024	0.059	0.061	0.068	0.000
CPR3 SYS	−5.974	−8.286	−4.654	3.031	3.030	3.030	1.000
MAD STAT	0.003	0.004	0.003	0.002	0.002	0.003	0.000
				Technology 3			
ACTUAL[c]	−1.104	−7.441	−5.156	1.707	1.707	0.751	1.012
PTWO SYS[c]	−1.113	−7.459	−5.165	1.713	1.716	0.758	1.012
MAD STAT[c]	0.023	0.037	0.034	0.028	0.038	0.094	0.000
PTHR SYS	−1.105	−7.442	−5.157	1.708	1.708	0.750	1.012
MAD STAT	0.002	0.007	0.005	0.003	0.003	0.005	0.000
CTWO SYS	−1.091	−7.446	−5.159	1.691	1.696	0.776	1.012
MAD STAT	0.033	0.191	0.099	0.060	0.043	0.044	0.001
CTHR SYS	−1.104	−7.438	−5.155	1.707	1.707	0.751	1.012
MAD STAT	0.001	0.009	0.003	0.003	0.001	0.003	0.000
CPR2 SYS	−1.093	−7.458	−5.162	1.696	1.699	0.770	1.012
MAD STAT	0.032	0.188	0.098	0.058	0.042	0.041	0.001
CPR3 SYS	−1.104	−7.439	−5.155	1.707	1.707	0.751	1.012
MAD STAT	0.001	0.009	0.003	0.002	0.001	0.002	0.000
				Technology 5			
ACTUAL[c]	−12.261	−0.413	−0.379	0.847	0.635	0.254	0.704
PTWO SYS[c]	−12.170	−0.424	−0.335	0.789	0.643	0.247	0.703
MAD STAT[c]	0.423	0.042	0.077	0.111	0.099	0.051	0.009
PTHR SYS	−12.204	−0.412	−0.380	0.845	0.632	0.255	0.703
MAD STAT	0.261	0.008	0.010	0.026	0.023	0.007	0.003
CTWO SYS	736.115	−0.401	−0.301	0.565	0.202	0.245	0.846
MAD STAT	748.893	0.057	0.088	0.625	0.656	0.047	0.281
CTHR SYS	−13.732	−0.364	−0.367	0.902	0.572	0.245	0.746
MAD STAT	2.691	0.108	0.056	0.232	0.208	0.072	0.090
CPR2 SYS	60.087	−0.397	−0.335	0.812	0.607	0.233	0.709
MAD STAT	73.295	0.050	0.068	0.256	0.212	0.043	0.034
CPR3 SYS	−12.526	−0.365	−0.354	0.746	0.619	0.241	0.701
MAD STAT	2.550	0.105	0.054	0.349	0.178	0.056	0.020
				Technology 7			
ACTUAL[c]	−1.908	−12.490	−9.343	3.540	2.950	−0.590	0.894
PTWO SYS[c]	−2.053	−12.850	−9.497	3.700	3.085	−0.599	0.893
MAD STAT[c]	0.221	0.567	0.341	0.281	0.325	0.725	0.004
PTHR SYS	−1.941	−12.549	−9.379	3.584	2.985	−0.642	0.894
MAD STAT	0.164	0.513	0.288	0.261	0.198	0.379	0.002
CTWO SYS	−1.770	−12.591	−9.229	3.400	2.790	−0.381	0.912
MAD STAT	0.239	1.238	0.755	0.415	0.319	0.419	0.063
CTHR SYS	−1.784	−12.269	−9.121	3.368	2.786	−0.362	0.905
MAD STAT	0.169	0.559	0.402	0.245	0.213	0.366	0.023
CPR2 SYS	−1.735	−12.470	−9.246	3.327	2.760	−0.306	0.896
MAD STAT	0.251	1.331	0.804	0.450	0.338	0.477	0.008
CPR3 SYS	−1.809	−12.423	−9.244	3.425	2.839	−0.485	0.899
MAD STAT	0.170	0.648	0.456	0.263	0.223	0.403	0.010

Table 2. Continued

Allen Partial Elasticities of Substitution						
AES11	AES22	AES33	AES12	AES13	AES23	Returns to Scale
Technology 2						
−1.341	−0.508	−0.515	0.333	0.333	0.333	1.000
−1.330	−0.505	−0.516	0.332	0.332	0.332	1.000
0.072	0.011	0.010	0.018	0.031	0.012	0.000
−1.340	−0.508	−0.515	0.333	0.333	0.333	1.000
0.002	0.003	0.002	0.002	0.001	0.002	0.000
−1.293	−0.495	−0.512	0.327	0.326	0.327	1.000
0.228	0.037	0.031	0.054	0.094	0.037	0.001
−1.338	−0.504	−0.513	0.330	0.335	0.331	0.999
0.007	0.008	0.005	0.006	0.004	0.005	0.004
−1.283	−0.496	−0.513	0.325	0.323	0.329	1.000
0.230	0.036	0.028	0.054	0.094	0.036	0.000
−1.338	−0.504	−0.513	0.331	0.334	0.331	1.000
0.007	0.008	0.005	0.006	0.004	0.005	0.000
Technology 4						
−7.822	−6.125	−1.688	1.072	1.787	2.502	0.959
−7.835	−6.133	−1.694	1.079	1.793	2.506	0.958
0.071	0.089	0.029	0.128	0.046	0.042	0.001
−7.825	−6.136	−1.693	1.065	1.792	2.510	0.959
0.032	0.059	0.024	0.036	0.025	0.036	0.001
−7.829	−6.138	−1.682	1.077	1.783	2.502	0.962
0.157	0.112	0.032	0.026	0.038	0.046	0.007
−7.812	−6.124	−1.685	1.077	1.782	2.500	0.962
0.025	0.016	0.007	0.010	0.008	0.007	0.005
−7.829	−6.138	−1.681	1.077	1.782	2.501	0.959
0.158	0.113	0.032	0.027	0.039	0.046	0.001
−7.815	−6.125	−1.686	1.076	1.784	2.501	0.959
0.024	0.015	0.006	0.008	0.006	0.006	0.001
Technology 6						
−1.010	−20.461	−16.926	3.609	2.578	−2.578	0.832
−1.394	−22.655	−17.982	4.330	3.132	−3.149	0.831
0.670	3.518	1.675	1.266	1.020	2.510	0.003
−0.657	−19.428	−16.401	2.998	2.142	−1.837	0.832
0.741	3.173	1.619	1.459	1.039	2.237	0.002
−0.633	−18.582	−15.692	2.548	1.738	0.303	0.857
0.395	6.465	4.060	1.286	0.952	3.288	0.165
−0.766	−19.220	−16.089	3.024	2.109	−1.518	0.847
0.284	2.930	1.816	0.808	0.640	2.144	0.033
−0.831	−22.901	−18.167	3.375	2.371	−2.716	0.835
0.287	6.519	3.738	0.964	0.650	2.285	0.021
−0.837	−20.890	−17.125	3.358	2.373	−2.862	0.846
0.292	3.870	2.389	0.924	0.727	2.821	0.022

[a] The six models are: second-order translog production system (PTWO), third-order translog production system (PTHR), second-order cost system (CTWO), third-order cost system (CTHR), second-order cost system, profit max. imposed (CPR2), and third-order cost system, profit max. imposed (CPR3).
[b] The technologies on which the Monte Carlo experiments are based are in table 1.
[c] The average of the actual parameter values and the estimated parameter values across all observations and replications; mean of the absolute deviations of the estimated values from the true values (MAD STAT error) averaged across all replications.

model performance are apparent from the results of the experiments using correctly measured data. These differences are taken up presently.

Cost systems versus production systems. Except for the inconsistent elasticity estimates for technology 5 obtained from the second-order models, the performance differences across dual models are minor.[4] In other words, for the technologies considered in this experiment, inferences obtained from the dual models regarding the underlying technology are reasonably consistent, especially for technologies 1–4. We refute the notion that the translog production and cost models will always yield widely varying inferences because they represent materially different maintained hypotheses about the underlying technology.

Second- and third-order system performance. Because third-order translog models are in a sense more flexible than their second-order counterparts, third-order translog systems might be expected to outperform second-order systems in terms of MAD errors. For the technologies explored in this experiment, this is always the case.[5]

Translog models are sometimes interpreted as Taylor-series approximations. A Taylor-series approximation to a differentiable function is uniformly convergent within a region of convergence $\mathfrak{R}$ (Dienes).[6] Uniform convergence implies that for any $\varepsilon > 0$, an N can be found such that the difference between an nth order approximation evaluated at arbitrary z in $\mathfrak{R}$ and the function evaluated at z is less than ε for all $n > N$, where N depends only on ε and not on the particular z in $\mathfrak{R}$. This implies that a translog model of sufficiently high order, if it can be interpreted as a Taylor-series expansion, will track any differentiable function over the entire region of convergence not just in the neighborhood of some point.

On the basis of an analysis using first-order expansions, White argues that it is inappropriate to interpret the estimated parameters of a translog model as Taylor-series coefficients. Byron and Bera note that the translog is seldom truncated at the first-order term and suggest that the bias of the translog coefficient estimates depends on the relative importance of the truncated terms. If the third (fourth) and higher-order terms of the underlying function are insubstantial, their omission in second- (third-) order approximations will not cause a serious omitted variables bias.

To assess the impact of omitting higher-order terms on the estimates of the Taylor-series coefficients and ultimately on estimates of the substitution elasticities, for a single replication of the experiment we compare estimates of the translog production function coefficients with the coefficients of a Taylor-series expansion in powers of $\ln x$.[7] The Taylor-series coefficients (log derivatives) have been calculated at the geometric mean of the data and at every data point for each of the generalized CES production functions. The first-, second-, and third-order Taylor-series coefficients evaluated at the mean of the data (point of expansion) are presented in table 3 along with second- and third-order translog production function estimates of these coefficients. The standard deviations of the Taylor-series coefficients (not the estimated coefficients) are also reported. The standard deviations are useful in determining the influence of yet higher-order derivatives.

With few exceptions, the translog estimates are remarkably close to the Taylor-series coefficients. Translog coefficient estimates are most biased for technology 5 (note D1L3, D2L33, and D3L33), and to a much lesser extent for technologies 6 and 7 (note D1L1). As Byron and Bera claim, biases arise only in situations where omitted higher-order terms are not insubstantial; however, biases do not always arise in such cases.[8] For technologies 1–4, translog coeffi-

---

[4] The second-order translog cost model had considerable trouble with technology 5. Only by relaxing the convergence criteria in SAS PROC SYSNLIN to 0.035 could this model be made to converge on a regular basis. With tighter criteria, the search procedure wandered off to some inappropriate region in the parameter space. The search continued until the maximum iterations were performed.

[5] The result holds in general only for those underlying functions for which the Taylor-series expansion is monotonically convergent. That is, the absolute value of the remainder term is reduced monotonically as higher-order terms are added to the expansion. Absolute convergence does not guarantee monotonic convergence. A general set of conditions under which the Taylor series is monotonically convergent could not be found.

[6] The radius of convergence is a sphere with radius equal to the distance between the point of expansion and the nearest singularity—a point where the function derivatives are undefined.

[7] Similar comparisons between coefficients of a Taylor-series expansion of the cost function and translog cost system coefficients are not possible because the generalized CES production function usually does not have a closed-form cost function representation.

[8] In spite of the large higher-order terms, the translog production models perform well on technology 2 because homogeneity guarantees that $\Sigma_k(\partial^3\ln y/\partial\ln x_i\partial\ln x_j\partial\ln x_k) = 0\ \forall i, j$. When the data are both scaled and very collinear, the magnitude of $\ln x_1$, $\ln x_2$, and $\ln x_3$ are similar at each observation; therefore, the sum $\Sigma_k(\partial^3\ln y/\partial\ln x_i\partial\ln x_j\partial\ln x_k)\ln x_i \ln x_j \ln x_k$ is likely to be close to zero for all i, j. Since the residual is not increased much when the third-order term is omitted, it should be no surprise that any resulting omitted variable bias is small.

cient bias is minimal and the translog tracks very well (note the small MAD errors for these technologies in table 2). For technology 5, the relatively large percentage MAD errors (especially of the second-order models) may be attributed to biased coefficient estimates. The poor tracking performance of the translog on technologies 6 and 7 appears to result from omitted higher-order terms (the standard errors for D3L11 are huge relative to the size of the Taylor-series coefficients at the mean) even though the estimated coefficients exhibit little omitted variables bias.

From the results, two commonly held notions can be refuted: (*a*) translog models always yield good estimates at the point of expansion and (*b*) translog estimates always deteriorate rapidly away from the point of expansion. Further, the results invalidate White's criticism and support the Byron and Bera claim that translog coefficient estimates converge to their Taylor-series counterparts if the order of expansion is sufficiently large. We add only the notion that the inclusion of sufficient high-order terms is essential for good tracking even when the omission of these high-order effects does not lead to biased coefficient estimates.

Byron and Bera have suggested testing estimated coefficients to determine whether the underlying function exhibits important high-order effects. Using a Scheffe test ($\alpha = .05$), with critical value S of 5.18 (based on $F_{10,40}$), the hypothesis that all third-order coefficients equal zero is rejected by a production (PTHR) and cost system (CTHR) for all technologies.[9] Each production (cost) system contains at least three (one) parameter estimates with t-statistics exceeding the critical value S. The tests correctly identify the superior model (that with smallest MAD errors) in every case.

Cost systems with and without a profit maximization condition. In systems CPR2 and CPR3, the profit maximization condition that output price equals marginal cost has been added to the standard cost system. In terms of AES performance, there is virtually no advantage to including the extra first-order condition in the cost system of equations. The performance gains come on returns-to-scale estimates and are especially noticeable for the second-order systems (see technologies 5, 6, and 7). Improvements in estimates of returns to scale come from the cross-equation restrictions on parameters of the cost function associated with output.

Regime 2—All Data Are Measured with Errors

For the second regime, data have been generated to reflect typical measurement errors associated with secondary data sources and to mimic the way in which share, input, and price series are constructed from one another. The elasticity estimates for all systems are reported in table 4. The estimates are biased, and MAD values have increased substantially over those reported for regime 1.

These results force a reevaluation of many previous Monte Carlo studies. In the experiments of Guilkey and Lovell; Guilkey, Lovell, and Sickles; and Dixon, Garcia, and Anderson, data are generated with errors, in some cases quite substantial (the Guilkey, Lovell, and Sickles data and the Dixon, Garcia, and Anderson data contain error components with standard deviation of 31%). Aside from the experiment of Chalfant and Gallant, there is no way of distinguishing between biases caused by the error components and tracking problems attributable to the flexible form. The results of the two error regimes suggest that performance problems often attributed to failures of the flexible form are in fact caused by errors in variables.

Cost system versus production systems. Under regime 2, the translog cost and production system estimates of the Allen partials exhibit a consistent pattern of bias. That is, production system estimates of own AES are negatively biased and cost system estimates are positively biased. Out of 126 possibilities in table 4, there are only 8 exceptions, 5 of which are associated with estimates of technology 5 (see footnote 4) and the remaining with elasticity estimates from the third-order production system. This pattern of results also was observed by Burgess using aggregate manufacturing data and by Lessner using farm-level data. The bias is more severe when substitution possibilities are easy.

The very disparate estimates obtained from production and cost models under regime 2 indicate that substantial differences in inferences

[9] The acceptance region of an α-level Scheffe test of the composite hypotheses H (all hypotheses true) is the same as the acceptance region of an α-level F-test of H. Therefore, if any of the individual t-statistics exceed the critical value S(cheffe), then an F test of H_0, all third-order parameters equal zero, would also be rejected. The Scheffe test is more informative than the F because it identifies the particular hypotheses responsible for rejection of the F. The results are available on request from the authors.

Table 3a. First- and Second-Order Coefficients of Taylor-Series Expansion in ln x Evaluated at the Geometric Mean of the Data (AT MEAN) and Second- and Third-Order Translog Production System Estimates of Them

	First-Order Coefficients[a]			Second-Order Coefficients					
	D1L1	*D1L2*	*D1L3*	*D2L11*	*D2L22*	*D2L33*	*D2L12*	*D2L13*	*D2L23*
Tech 1—2nd-Order Translog									
ESTIMATE	0.334987	0.267212	0.397803	0.149004	0.130649	0.159536	−0.060020	−0.088966	−0.070604
AT MEAN	0.336556	0.264038	0.399405	0.149601	0.130195	0.160720	−0.059538	−0.090063	−0.070657
STD ERR[b]	0.034969	0.040528	0.038917	0.002472	0.004407	0.001409	0.002243	0.003527	0.003026
Tech 1—3rd-Order Translog									
ESTIMATE	0.335037	0.267012	0.397951	0.149192	0.131045	0.160434	−0.059912	−0.089284	−0.071141
AT MEAN	0.336556	0.264038	0.399405	0.149601	0.130195	0.160720	−0.059538	−0.090063	−0.070657
STD ERR	0.034969	0.040528	0.038917	0.002472	0.004407	0.001409	0.002243	0.003527	0.003026
Tech 2—2nd-Order Translog									
ESTIMATE	0.206789	0.406365	0.386843	−0.325506	−0.479297	−0.474875	0.164964	0.160541	0.314334
AT MEAN	0.201972	0.416766	0.381261	−0.322359	−0.486144	−0.471802	0.168350	0.154008	0.317793
STD ERR	0.037164	0.103080	0.050828	0.031421	0.019560	0.015404	0.015215	0.028357	0.019642
Tech 2—3rd-Order Translog									
ESTIMATE	0.206096	0.405804	0.388094	−0.326592	−0.477429	−0.472021	0.166030	0.160582	0.311417
AT MEAN	0.201972	0.416766	0.381261	−0.322359	−0.486144	−0.471802	0.168350	0.154008	0.317793
STD ERR	0.037164	0.103080	0.050828	0.031421	0.019560	0.015404	0.015215	0.028357	0.019642
Tech 3—2nd-Order Translog									
ESTIMATE	0.622870	0.164400	0.228180	0.262444	0.030765	0.037041	−0.040558	−0.057371	−0.015632
AT MEAN	0.629407	0.162722	0.227424	0.263241	0.030089	0.036167	−0.040967	−0.057257	0.014802
STD ERR	0.100053	0.021356	0.012483	0.008582	0.001237	0.000616	0.000809	0.002448	0.001512
Tech 3—3rd-Order Translog									
ESTIMATE	0.622008	0.164404	0.228507	0.261231	0.030241	0.036182	−0.040772	−0.056693	−0.015035
AT MEAN	0.629407	0.162722	0.227424	0.263241	0.030089	0.036167	−0.040967	−0.057257	−0.014802
STD ERR	0.100053	0.021356	0.012483	0.008582	0.001237	0.000616	0.000809	0.002448	0.001512

Tech 4—2nd-Order Translog									
ESTIMATE	0.157204	0.250259	0.555562	0.033647	0.090642	0.218192	−0.021861	−0.047933	−0.075925
AT MEAN	0.156391	0.248066	0.560520	0.033465	0.090187	0.219563	−0.021337	−0.048213	−0.076475
STD ERR	0.013492	0.030526	0.080791	0.001048	0.002591	0.003276	0.002083	0.000773	0.001715
Tech 4—3rd-Order Translog									
ESTIMATE	0.157232	0.250383	0.555325	0.033508	0.090548	0.218496	−0.021723	−0.047859	−0.076213
AT MEAN	0.156391	0.248066	0.560520	0.033465	0.090187	0.219563	−0.021337	−0.048213	−0.076475
STD ERR	0.013492	0.030526	0.080791	0.001048	0.002591	0.003276	0.002083	0.000773	0.001715
Tech 5—2nd-Order Translog									
ESTIMATE	0.048868	0.292963	0.327561	−0.004861	−0.451031	−0.690830	0.031503	0.025665	0.203921
AT MEAN	0.050324	0.317677	0.268614	−0.004999	−0.433517	−0.661536	0.031974	0.027035	0.170665
STD ERR	0.018418	0.123665	0.155428	0.000338	0.019310	0.241087	0.005857	0.006646	0.097426
Tech 5—3rd-Order Translog									
ESTIMATE	0.048952	0.315523	0.292443	−0.004764	−0.422155	−0.700131	0.029369	0.027409	0.192673
AT MEAN	0.050324	0.317677	0.268614	−0.004999	−0.433517	−0.661536	0.031974	0.027035	0.170665
STD ERR	0.018418	0.123665	0.155428	0.000338	0.019310	0.241087	0.005857	0.006646	0.097426
Tech 6—2nd-Order Translog									
ESTIMATE	0.663437	0.100344	0.079833	0.499414	0.039499	0.017000	−0.071658	−0.056887	−0.009370
AT MEAN	0.679546	0.097875	0.078092	0.511358	0.038400	0.016719	−0.073162	−0.058374	−0.008407
STD ERR	0.183682	0.015624	0.010732	0.016892	0.004517	0.001663	0.002509	0.001946	0.002789
Tech 6—3rd-Order Translog									
ESTIMATE	0.663550	0.100367	0.079795	0.499590	0.038880	0.016790	−0.071623	−0.056943	−0.009003
AT MEAN	0.679546	0.097875	0.078092	0.511358	0.038400	0.016719	−0.073162	−0.058374	−0.008407
STD ERR	0.183682	0.015624	0.010732	0.016892	0.004517	0.001663	0.002509	0.001946	0.002789
Tech 7—2nd-Order Translog									
ESTIMATE	0.576731	0.152305	0.168428	0.366650	0.058827	0.045817	−0.069292	−0.077893	−0.021866
AT MEAN	0.585883	0.149718	0.167177	0.369864	0.056926	0.044512	−0.070173	−0.078357	−0.020023
STD ERR	0.120213	0.023704	0.011897	0.012233	0.003990	0.001802	0.001645	0.003297	0.003636
Tech 7—3rd-Order Translog									
ESTIMATE	0.575688	0.152301	0.168821	0.365044	0.057415	0.044544	−0.069542	−0.077101	−0.020646
AT MEAN	0.585883	0.149718	0.167177	0.369864	0.056926	0.044512	−0.070173	−0.078357	−0.020023
STD ERR	0.120213	0.023704	0.011897	0.012233	0.003990	0.001802	0.001645	0.003297	0.003636

[a] Where, for instance, $D1L2$ is $\partial \ln y/\partial \ln x_2$ and $D2L12$ is $\partial^2 \ln y/\partial \ln x_1 \partial \ln x_2$.
[b] STD ERR denotes the standard error associated with Taylor-Series coefficients over the range of the data.

Table 3b. Third-Order Coefficients of Taylor-Series Expansion in ln x Evaluated at the Geometric Mean of the Data (AT MEAN) and Third-Order Translog Production System Estimates of These Coefficients

	Third-Order Coefficients[a]									
	*D3L*11	*D3L*12	D3L13	*D3L*21	*D3L*22	*D3L*23	*D3L*31	*D3L*32	*D3L*33	*D3L*123
Tech 1										
ESTIMATE	0.032473	−0.013281	−0.019260	−0.019443	0.041273	−0.021530	−0.013153	−0.011026	0.023931	0.032585
AT MEAN	0.032765	−0.013039	−0.019725	−0.018825	0.041166	−0.022341	−0.012140	−0.009524	0.021664	0.031865
STD ERR[b]	0.001715	0.001076	0.000897	0.000728	0.001106	0.000686	0.000998	0.001090	0.001922	0.000453
Tech 2										
ESTIMATE	0.385102	−0.193969	−0.190629	−0.049756	0.178096	−0.128635	−0.056694	−0.118628	0.178591	0.245478
AT MEAN	0.384287	−0.200692	−0.183595	−0.056050	0.161855	−0.105805	−0.073147	−0.150937	0.224084	0.256742
STD ERR	0.006930	0.018896	0.021114	0.031836	0.089671	0.058798	0.018069	0.048032	0.061752	0.018232
Tech 3										
ESTIMATE	0.041612	−0.006317	−0.008807	−0.005035	0.003857	−0.00184	−0.004173	−0.000989	0.002622	0.007310
AT MEAN	0.043822	−0.006820	−0.009531	−0.004908	0.003605	−0.001773	−0.003896	−0.001007	0.002461	0.007453
STD ERR	0.009331	0.001547	0.001937	0.000425	0.000104	0.000060	0.000569	0.000016	0.000215	0.000160
Tech 4										
ESTIMATE	0.002549	−0.004889	−0.002502	−0.007976	0.017410	−0.011315	−0.011768	−0.016392	0.034641	0.017988
AT MEAN	0.004282	−0.002730	−0.006169	−0.004846	0.020484	−0.017369	−0.004022	−0.006380	0.018317	0.013156
STD ERR	0.000177	0.000084	0.000494	0.000213	0.000567	0.001231	0.001762	0.002743	0.007946	0.000441
Tech 5										
ESTIMATE	0.000051	−0.000370	−0.000074	−0.016501	0.209862	−0.067484	−0.042411	−0.338270	1.142440	0.029365
AT MEAN	−0.000006	0.000041	0.000035	−0.023318	0.316159	−0.124464	−0.052058	−0.328623	1.273815	0.034354
STD ERR	0.000201	0.001207	0.001301	0.006056	0.023058	0.074777	0.012175	0.089794	0.291350	0.009378
Tech 6										
ESTIMATE	−0.008570	0.001279	0.000945	−0.020920	0.010136	−0.001727	−0.007565	−0.001544	0.002524	0.012295
AT MEAN	0.002555	−0.000365	−0.000291	−0.020827	0.010931	−0.002393	−0.007483	−0.001077	0.002143	0.012569
STD ERR	0.118050	0.016924	0.013456	0.002598	0.000301	0.000470	0.001583	0.000112	0.000269	0.001925
Tech 7										
ESTIMATE	0.053422	−0.010058	−0.011015	−0.018608	0.015488	−0.005335	−0.010936	−0.002668	0.006322	0.018471
AT MEAN	0.060135	−0.011409	−0.012739	−0.018276	0.014826	−0.005215	−0.010383	−0.002653	0.005898	0.018770
STD ERR	0.038717	0.007501	0.008082	0.002016	0.000410	0.000449	0.002033	0.000091	0.000700	0.001165

[a] Where, for instance, *D3L*12 denotes $\partial^3 \ln y / \partial \ln x_1^2 \partial \ln x_2$.
[b] STD ERR denotes the standard error associated with Taylor-Series coefficients over the range of the data.

obtained from dual models are more likely to result from errors in data measurement than from the different maintained hypotheses of the translog cost and production models or from complicated matrix inversions.

What accounts for the biased estimates of the elasticities? Mismeasured data can result in two types of bias; errors in variables and simultaneity. Simultaneity occurs, for instance, in a cost system if prices are constructed from mismeasured expenditures and inputs. Cost and expenditure equation errors are then correlated with prices, and a simultaneity problem results. If mismeasured inputs are collected or constructed independently of expenditures, simultaneity does not occur in the corresponding production model. However, because simultaneity bias may either reinforce or counteract the errors in variables bias and the severity of the errors in variables bias is likely to differ across the dual models, there are no theoretical grounds for preferring either the production or cost model when both prices and inputs are known to be measured with errors even if one system is known to be free of simultaneity. In this experiment, data have been generated so that simultaneity plagues both systems.

Second- and third-order system performances. When data are measured with errors, it is inappropriate to regard translog coefficient estimates as Taylor-series coefficients. Convergence is no longer guaranteed and second-order systems perform at least as well as their third-order counterparts. Across all technologies, estimates of AES from the second-order production system have much smaller MAD values than third-order production system estimates. Among the cost systems, there is no corresponding deterioration in elasticity estimates of the third-order systems; however, there is no improvement either.[10]

[10] Input data are more collinear than price data in this experiment. This may account for the extreme deterioration in the third-order production system estimates relative to third-order cost system estimates.

Table 4. Summary of Monte Carlo Results from Regime 2—All Data Measured with Error

Models[a]	Allen Partial Elasticities of Substitution						Returns to Scale
	AES11	AES22	AES33	AES12	AES13	AES23	
				Technology 1[b]			
ACTUAL[c]	−5.978	−8.302	−4.645	3.030	3.030	3.030	1.000
PTWO SYS[c]	−6.774	−7.970	−4.931	3.129	3.633	2.707	0.999
MAD STAT[c]	1.173	1.328	0.797	0.710	0.929	0.698	0.003
PTHR SYS	−24.856	−11.429	−22.104	−0.834	20.682	8.130	0.999
MAD STAT	23.747	13.255	23.018	11.552	21.514	11.355	0.004
CTWO SYS	−2.108	−2.613	−1.604	0.977	1.133	0.937	1.008
MAD STAT	3.869	5.689	3.041	2.054	1.897	2.094	0.023
CTHR SYS	−2.107	−2.636	−1.622	0.972	1.137	0.956	1.011
MAD STAT	3.872	5.667	3.023	2.064	1.900	2.078	0.036
CPR2 SYS	−2.622	−3.281	−1.755	1.432	1.261	1.000	0.999
MAD STAT	3.356	5.021	2.890	1.599	1.769	2.030	0.004
CPR3 SYS	−2.637	−3.248	−1.766	1.422	1.281	0.988	0.999
MAD STAT	3.342	5.054	2.879	1.618	1.760	2.044	0.005
				Technology 3			
ACTUAL[c]	−1.104	−7.441	−5.156	1.707	1.707	0.751	1.012
PTWO SYS[c]	−1.356	−8.254	−6.592	1.893	2.223	0.856	1.011
MAD STAT[c]	0.252	0.956	1.437	0.212	0.515	0.389	0.006
PTHR SYS	−1.460	−9.050	−7.407	2.008	2.444	1.076	1.011
MAD STAT	0.375	2.448	2.592	0.493	0.813	1.367	0.006
CTWO SYS	−0.684	−4.834	−3.598	0.987	1.111	0.817	1.019
MAD STAT	0.421	2.607	1.558	0.721	0.596	0.322	0.026
CTHR SYS	−0.683	−4.880	−3.599	0.991	1.107	0.835	1.021
MAD STAT	0.431	2.624	1.638	0.725	0.649	0.737	0.035
CPR2 SYS	−0.939	−5.878	−4.187	1.446	1.462	0.319	1.011
MAD STAT	0.170	1.565	0.974	0.265	0.267	0.464	0.006
CPR3 SYS	−0.938	−5.872	−4.175	1.447	1.461	0.309	1.012
MAD STAT	0.186	1.704	1.106	0.296	0.329	0.670	0.007
				Technology 5			
ACTUAL[c]	−12.254	−0.414	−0.383	0.845	0.634	0.254	0.701
PTWO SYS[c]	−15.044	−0.443	−0.350	0.924	0.782	0.243	0.700
MAD STAT[c]	2.917	0.062	0.083	0.194	0.213	0.054	0.018
PTHR SYS	−15.992	−0.482	−0.436	1.047	0.808	0.280	0.700
MAD STAT	5.310	0.085	0.084	0.391	0.307	0.046	0.015
CTWO SYS	290.614	−0.435	−0.182	0.802	−0.682	0.263	0.742
MAD STAT	302.991	0.094	0.205	0.452	1.519	0.080	0.105
CTHR SYS	−14.924	−0.315	−0.282	1.082	0.379	0.193	0.893
MAD STAT	6.080	0.138	0.136	0.445	0.422	0.106	0.261
CPR2 SYS	190.852	−0.419	−0.355	0.761	0.521	0.264	0.708
MAD STAT	203.691	0.083	0.081	0.430	0.367	0.063	0.041
CPR3 SYS	−49.650	−0.322	−0.354	1.164	0.526	0.225	0.680
MAD STAT	40.416	0.139	0.077	0.601	0.430	0.096	0.030
				Technology 7			
ACTUAL[c]	−1.915	−12.491	−9.343	3.544	2.953	−0.591	0.894
PTWO SYS[c]	−2.489	−13.205	−11.895	4.045	4.047	−1.283	0.893
MAD STAT[c]	0.800	1.915	2.801	0.892	1.326	1.577	0.006
PTHR SYS	−2.628	−15.175	−13.444	4.540	4.482	−1.999	0.893
MAD STAT	1.204	7.333	7.938	1.958	2.525	4.802	0.007
CTWO SYS	−0.584	−4.666	−4.568	0.934	1.069	1.033	0.902
MAD STAT	1.332	7.825	4.775	2.610	1.885	1.627	0.030
CTHR SYS	−0.594	−4.694	−4.607	0.961	1.096	0.934	0.902
MAD STAT	1.324	7.799	4.762	2.584	1.874	1.769	0.035
CPR2 SYS	−1.158	−7.619	−5.922	2.154	1.871	−0.535	0.892
MAD STAT	0.758	4.878	3.423	1.391	1.087	0.622	0.010
CPR3 SYS	−1.187	−7.610	−5.931	2.204	1.923	−0.706	0.896
MAD STAT	0.733	4.917	3.445	1.356	1.054	0.948	0.013

Table 4. Continued

Allen Partial Elasticities of Substitution						
AES11	AES22	AES33	AES12	AES13	AES23	Returns to Scale
Technology 2						
−1.336	−0.509	−0.517	0.333	0.333	0.333	1.000
−1.675	−0.664	−0.837	0.269	0.576	0.522	0.999
0.343	0.155	0.319	0.069	0.243	0.189	0.004
−1.767	−0.725	−0.881	0.272	0.617	0.561	0.999
0.466	0.262	0.457	0.138	0.324	0.292	0.004
−1.226	−0.475	−0.505	0.304	0.319	0.320	1.008
0.261	0.061	0.052	0.071	0.108	0.055	0.026
−1.296	−0.487	−0.514	0.308	0.339	0.326	1.009
0.176	0.108	0.129	0.091	0.113	0.104	0.034
−1.238	−0.477	−0.500	0.313	0.315	0.317	0.999
0.256	0.059	0.052	0.063	0.108	0.053	0.003
−1.309	−0.488	−0.509	0.315	0.340	0.322	1.001
0.171	0.071	0.091	0.075	0.103	0.068	0.006
Technology 4						
−7.853	−6.143	−1.680	1.072	1.786	2.501	0.959
−9.393	−6.382	−1.928	0.853	2.339	2.676	0.959
1.685	0.728	0.300	0.587	0.630	0.374	0.004
−7.498	−7.075	−1.962	0.429	1.933	3.077	0.959
8.084	5.177	1.555	4.151	2.541	2.281	0.004
−5.135	−2.726	−0.741	1.012	1.026	0.954	0.968
2.717	3.417	0.939	0.317	0.761	1.547	0.024
−5.139	−2.758	−0.745	1.035	1.019	0.963	0.972
2.835	3.391	0.936	0.621	0.827	1.540	0.038
−5.014	−3.286	−0.843	1.036	0.980	1.203	0.959
2.838	2.858	0.837	0.298	0.806	1.298	0.004
−5.017	−3.289	−0.843	1.046	0.978	1.203	0.958
2.929	2.865	0.839	0.487	0.849	1.303	0.005
Technology 6						
−1.007	−20.564	−17.030	3.601	2.572	−2.572	0.834
−1.260	−27.075	−24.061	4.172	3.178	1.043	0.833
0.724	9.835	8.060	1.587	1.462	7.260	0.010
0.937	−15.904	−18.488	0.417	0.708	1.007	0.833
2.892	19.841	12.918	5.902	4.509	11.527	0.010
−0.217	−6.149	−8.335	0.704	0.715	2.061	0.846
0.790	14.416	8.725	2.897	1.857	4.637	0.068
−0.265	−6.898	−9.517	0.892	0.958	0.919	0.844
0.743	13.732	7.695	2.715	1.637	4.089	0.038
−0.565	−14.014	−12.333	2.175	1.700	−2.282	0.834
0.447	8.421	5.620	1.506	0.973	2.468	0.021
−0.624	−13.324	−13.352	2.318	2.030	−3.542	0.842
0.409	7.728	4.709	1.388	0.816	2.780	0.020

[a] The six models are: second-order translog production system (PTWO), third-order translog production system (PTHR), second-order cost system (CTWO) third-order cost system (CTHR), second-order cost system, profit max. imposed (CPR2), and third-order cost system, profit max. imposed (CPR3).

[b] The technologies on which the Monte Carlo experiments are based are in table 1.

[c] The average of the actual parameter values and the estimated parameter values across all observations and replications: mean of the absolute deviations of the estimated values from the true values (MAD STAT error) averaged across all replications.

In general, when data are measured with errors, performance advantages are unlikely to be obtained by employing a third-order system, and doing so introduces considerable risk of large MAD errors. When deciding whether to employ a higher-order expansion, the t-statistics give good guidance under the measurement errors regime as well. Using the Scheffe test, not one third-order coefficient was statistically significant in any of the models for any technology. One would correctly opt for the better performing second-order system. The small t-ratios imply that the third-order terms in the model add little explanatory power, serve only to inflate the variances of parameter estimates, and should therefore be dropped.

The power of the Scheffe test under the errors in measurement regime is a surprise. Some third-order coefficients were expected to accrue enough bias to result in a rejection of H_0: second-order model correct. Apparently, this should not be a grave concern.

Conclusions

The results of these Monte Carlo experiments force a reevaluation of past experiments in which measurement errors have been simulated. First, the second-order translog provides serviceable estimates over a wide range of technologies previously considered difficult to model (Guilkey, Lovell, and Sickles) provided the data are measured accurately. In many previous studies on the relative performances of different flexible forms, differentiating between errors in variables (simultaneity) bias and poor tracking capabilities of the functional forms has been difficult if not impossible. Our results suggest that huge improvements in tracking performance are not likely to be achieved by searching for new, improved flexible forms but rather through better data measurement and perhaps improved methods for dealing with errors in variables.

Second, for many of the technologies investigated in this experiment, translog cost and production specifications do not yield materially different inferences regarding the underlying technology. Thus, one cannot argue that different maintained hypotheses always account for divergent inferences obtained from cost and production systems.

Third, experiments conducted with data measured with errors reveal the extreme sensitivity of elasticity estimates to errors in variables. Even with the modest errors introduced in these experiments, the MAD errors of AES elasticity estimates increase substantially across all models. In the presence of measurement errors, cost model estimates of the own AES are nearly always positively biased and production model estimates of the own AES usually obtain a negative bias. The same disparities between cost and production system estimates of elasticities were found by Burgess and by Lessner using actual data. These experiments indicate that substantial differences in cost and production system estimates are more likely to arise from data measurement errors than from the different hypotheses about production structure maintained in the translog cost and production systems.

In terms of positive prescriptions for production modeling, two important lessons can be drawn from the experiments. First, when data are measured with even modest amounts of error, there appear to be no performance gains from the third-order models, and there is a substantial risk of introducing large MAD error with the third-order models. In spite of some initial apprehensions, Scheffe (or F) tests were quite useful in assessing the order of expansion that the data will support.

Second, it is useful to estimate both production and cost systems. If elasticity estimates are consistent across both models, measurement errors are probably minimal. On the other hand, gross inconsistencies are a sure sign that at least one, but probably both, models are misspecified (omitted higher-order terms, misspecified dynamics, etc.) or that data measurement problems are severe. When data measurement errors are the only misspecification problem suspected, the translog cost and production system estimates of the Allen own partial elasticities of substitution can be expected to be biased in opposite directions. Estimates from the dual models can then serve as bounds on the true elasticity values.

[Received August 1990; final revision received December 1990.]

References

Berndt, E. R., and D. O. Wood. "Technology, Prices and the Derived Demand for Energy." *Rev. Econ. and Statist.* 57(1975):259–68.

Brown, R. "Productivity, Returns and the Structure of Production in U.S. Agriculture, 1947–1974." Ph.D. thesis, University of Wisconsin, 1978.

A Bioeconomic Analysis of the Texas Shrimp Fishery and Its Optimal Management

Hayri Önal, Bruce A. McCarl, Wade L. Griffin, Gary Matlock, and Jerry Clark

Overfishing in the Texas shrimp fishing industry by time period and fishing area is investigated. An optimal harvesting pattern is determined using a multiperiod mathematical programming model where prices, fishing effort, catch, and resource dynamics are treated endogenously. These results are then compared with actual effort. The comparison indicates substantial excess effort in spring and early summer, especially in the bays and shallow offshore areas. The peak fishing season also occurs later in the fall in optimal harvest pattern than in practice. The results indicate both producers and consumers gain from reduced fishing effort because of improved size composition of the harvest.

Key words: mathematical programming, optimal harvest, resource dynamics, shrimp fishery.

Texas is a major food shrimp-producing state, contributing about 30% of the total U.S. reported domestic commercial fleet landings. During 1963–85, reported Texas landings varied between 25 and 57 million pounds without an observable trend. Fishing effort (days fished), on the other hand, increased from 64,000 days in the early 1960s to 109,000 days by the mid-1980s. As a result, catch per unit of fishing effort declined.

During the shrimp life cycle, which is about one year, the shrimp stock is subject to natural and fishing mortality. Moreover, juvenile shrimp, which grow in marshes, move to bays and Gulf of Mexico waters as they grow. Thus, a trade-off occurs in catching shrimp in various seasons and locations. Small shrimp caught in bays are less valuable than larger shrimp caught in the Gulf, but catches by the bay fishermen reduce the stocks available to offshore fishermen. The open access, common property nature of the fishery motivates fishermen to harvest as much and as fast as they can. This lack of cooperation may lead to uneconomic use of the resource because the opportunity cost of the resource to an individual producer is not the same as it is to the industry as a whole.

To improve the economic efficiency of fishing, various regulatory measures have been taken. Until 1981 the fishery was managed by the state of Texas, but regulatory authority was limited to bay waters and shoreline to 9 nautical miles. Management efforts included season and area closures as well as size restrictions. When the United States went to a 200-mile extended jurisdiction, the State of Texas and the Gulf of Mexico Fisheries Council began joint management efforts. Currently the chief management tool is a forty-five- to sixty-day closure of the 200-mile area during late spring and early summer (although white shrimp can still be fished for in 1- to 4-fathom water). Much of the analysis on the Texas shrimp fishery has addressed this closure (e.g., Griffin et al. 1983; Jones, Klima, and Poffenberger; Nance and Nichols). The literature indicates, in general, that (*a*) overfishing may occur at least in some seasons, and

Hayri Önal is an assistant professor, Department of Agricultural Economics, University of Illinois; Bruce A. McCarl and Wade L. Griffin are professors, Department of Agricultural Economics, Texas A&M University; Gary Matlock is the Director of Fisheries, Texas Parks and Wildlife Department; and Jerry Clark is Assistant Secretary, Office of Fisheries, State of Louisiana.

Technical Paper TA 25981 of the Texas Agricultural Experiment Station.

This research was funded by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Sciences, through MARFIN contract NA87WC-H-06139.

(*b*) the timing of fishing activities might not be proper. These factors together affect the amount and size composition of harvest and may yield far below the optimum economic return to the fishery.

This paper presents an analysis of whether the Texas commercial food shrimp fishery is subject to excessive effort. Furthermore, if excess effort is found, then its incidence by time period and location will be analyzed. A mathematical programming model will be used to generate the optimal fishing effort and harvest pattern by location and time period.

Fishery Management Modeling: A Review

The simplest policy tool for studying the optimal management of fisheries is based on the maximum sustainable yield (MSY) concept. However, MSY does not incorporate economic considerations. Concerns about economic considerations led to approaches that maximize economic benefits subject to biological properties. Griffin, Lacewell, and Nichols used an analytical model of the Gulf shrimp industry to maximize overall rent given constant prices, cost functions, and yield-effort relations. However, their aggregate approach did not consider temporal and spatial issues which are important in the problem described above.

Optimal control (OC) theory and continuous dynamic programming (DP) have found wide theoretical acceptance among fishery analysts (Clark, Sadeh et al.). Harvest level and/or timing typically are treated as control variables. Most of the work with both approaches has focused on the derivation under restrictive assumptions and qualitative interpretation of the optimality conditions rather than numerical solutions. Discrete DP offers some computational advantage, but this approach suffers from the curse of dimensionality (Karp, Sadeh, and Griffin; Anderson et al.). The need for endogenous effort as well as the desired spatial and temporal dimensions make numerical or analytical OC and DP solutions too complex for the present problem.

Linear programming (LP) applications have appeared in the fishery literature for more than a decade (Rothschild and Balsiger; Siegel, Mueller, and Rothschild; Murakowski and Finn; Meuriot and Gates; Haynes and Pascoe). Using LP in fishery analysis has two disadvantages. The first is the frequently made assumption of constant per unit price and cost. This problem is not serious, however, because linear approximation procedures can be applied without much loss of solution accuracy (McCarl and Önal). The second, and more important, disadvantage is the difficulty of incorporating yield-effort-stock relationships. Stock usually is considered constant and exogenous in the literature. Most studies also assume that catch is proportional to fishing effort, although nonlinear catch-effort relations have also been incorporated using linear approximation techniques (Haynes and Pascoe).

Exogenous stock assumptions assume away an important feature of the fishery, namely dynamic changes in the resource stock which result from fishing effort. Such an assumption is valid in a single-period model where recruitment is not a function of stock, the stock is homogenous in terms of size, and migration is unimportant. However, these dynamic relations are crucial in an analysis of the Texas shrimp fishery because the fishing effort applied to a given stock at a place and time influences stock abundance and size composition at other places and times. Therefore, a proper model for this case must introduce endogenous catch/effort/stock relationships.[1]

Simulation has been frequently used in fishery management analysis, (e.g., Griffin et al., Grant and Griffin, Nance and Nichols). This approach allows nonlinear catch-per-unit-effort or cost functions. In addition, simulation, once parameterized, can overcome the lack of biological data by generating them. However, when the optimal harvesting plan is of interest, the alternatives to be simulated can be unmanageably large. Simulation has also been combined with optimization to benefit from the convenience of both approaches (Blomo et al. 1978, 1982). However, the number of control variables can be a restrictive factor in this approach.

In this study, a nonlinear programming model is developed using price-endogenous programming (McCarl and Spreen). This approach makes it possible to incorporate price-responsive demand functions. The constraints describe the biological characteristics of the system and endogenous resource dynamics through catch/effort/stock relationship. In this way, the optimization model exhibits the computational advantage of mathematical programming without ignoring the dynamic behavior of the Texas

[1] Haynes and Pascoe modeled population dynamics effects of current fishing policies on future stocks but this was done iteratively. They used a single-year, single-period model and computed the resource stock in the next year recursively between solutions assuming a nonlinear stock-recruitment relation without feedback. This procedure does not yield the optimum pattern over time.

shrimp fishery. The detailed algebraic structure and assumptions of the model are presented in the following sections.

Problem Setting and Methodology

The mathematical programming model used in this study depicts intertemporal linkages between stock and fishing effort in a year as well as the interaction between supply and demand of different product categories. Because Texas is a major shrimp producer in the United States, ex-vessel prices are treated as endogenous. The model explicitly depicts Texas effort and landings as well as shrimp supply from other Gulf states and imports. Texas landings are determined by fishing effort and stock abundance.

Two shrimp species (browns and whites) dominate the Texas industry. Once fishing effort is applied in an area, all shrimp cohorts larger than the mesh size are subject to catch. The model applies the same effort to all cohorts by species in a fishing area and time period.

The one-year shrimp life cycle is modeled in a one-year equilibrium model. Shrimp enter into the fishery year round, with the peak recruitment taking place in early spring. Carry-over shrimp coexist with beginning stocks. Thus, catches occurring in winter and spring can be either new shrimp or carry-over shrimp from the previous year. The model treats the entire stock by assuming that the stock in each period of the year, including the carry-over stock, equals the stock at that time in previous years. Thus, the biological system is assumed to be in dynamic equilibrium with respect to the effort level and repeats itself continuously. A parent-stock recruitment relationship is ignored, but it is assumed that in each fishing area the natural stock of any cohort at any period within a year depends on the level of stock in the previous period as well as catch, natural mortality, and in-and-out migration.

The model uses downward-sloping monthly linear demand functions for each size class of shrimp.[2] No seasonality in total demand is specified. Thus, the demand functions are the same for all months in a year but differ by size class. On the other hand, upward-sloping linear supply functions by size class and month are incorporated for Gulf supplies and imports. Thus, the excess demand facing Texas varies seasonally. Texas supplies vary due to endogenous catch, which is a function of available stock and the distribution of effort.

The Algebraic Structure of the Model

The model maximizes the objective function:

$$(1)\quad \sum_k \sum_m \{DEM_{km} * (a_k - 0.5 * A_k * DEM_{km}) - OTH_{km} * (b_k + 0.5 * B_k * OTH_{km}) - IMP_{km} * (g_k + 0.5 * G_k * IMP_{km})\} - \left\{\sum_s \sum_z \sum_t \sum_n c_{zt} * EFF_{sztn} + \sum_k \sum_m cs_k * STOR_{km}\right\},$$

subject to constraints (2) through (12) as described below. Definitions of the model, the subscripts, parameters, and variables are found in table 1. The objective function represents the sum of areas under the demand functions minus the sum of areas under the rest of the Gulf supply and import supply functions, minus the total cost of fishing and cold storage holdings.

The first constraint set limits the monthly endogenous effort for each vessel class to the specified monthly fishing capacity:

$$(2)\quad \sum_z \sum_s \sum_n nw_n * d_{nm} * EFF_{sztn} \le ec_{tm} \text{ for all } t, m.$$

The second constraint set sums efforts spent by all vessels (after converting to standard effort) directed to a species. These constraints are defined for each area and time period as follows:

$$(3)\quad \sum_t fc_t * EFF_{sztn} - TEF_{szn} = 0 \text{ for all } s, z, n.$$

The third constraint set depicts the catch/effort/stock relationship which is assumed to be given by[3]

$$(1a)\quad CATCH = \gamma * TEF^{\alpha} * STO^{1-\alpha}, \quad \gamma > 0, 0 < \alpha < 1$$

[2] The demand functions represent the excess demand for Gulf and import shrimp. Because Atlantic and Pacific landings constitute a small share of the total shrimp market, the demand functions represent most of the overall U.S. market demand.

[3] This form implies constant returns to scale, and it is different than the conventional multiplicative form, i.e., $CATCH = \gamma * TEF * STO$. A statistical justification is not available for either form in this particular fishery. This form is chosen for its mathematical convenience, namely the convexity properties.

Table 1. Notation Used in the Model

Subscripts	Definitions
h	Cohort
k	Size class
m	Month
n	Fishing period
$\hat{n}$	Periods in which cohorts are introduced
r	Grid point for the approximation
z	Depth zone
Parameters	
a, b, g	Vectors of demand, other Gulf supply and import supply intercepts for shrimp of size k
A, B, G	Vectors of demand, other Gulf supply and import supply slopes for shrimp of size k
bs_{zh}	Beginning stock of cohort h, at depth zone z
cs_k	Monthly cost per unit cold storage to store shrimp of size k
c_{zt}	Cost of a unit of effort directed to zone z using technology t
d_{nm}	Fishing period-to-month mapping parameter which takes the value 1 if fishing period n is mapped to month m, and 0 otherwise
ec_{tm}	Effort capacity for technology t in month m
e_r, s_r, f_r	Effort, stock and catch levels associated with approximation point r used in linearizing the stock, catch, effort functions
fc_t	Parameter that converts effort by vessel class t into a standard unit of effort
nw_n	Number of weeks shrimping occurs in fishing period n
q_{knh}	Size classification parameter which takes the value 1 if cohort h is of size class k in period n, otherwise 0
sc	Monthly cold storage limit
u_{hnz}, v_{hnz}	Mortality and migration rates specified by cohort time period and depth zone
w_{nh}	Weight that cohort h reaches in time period n
Variables	
APR_{hznr}	Linear approximation variable associated with grid point r, for cohort h, depth zone z, and time period n
$CATCH_{znh}$	Catch (in tails) of cohort h, in depth zone z and period n
DEM_{km}	Demand (in lbs.) for size k in month m
EFF_{tszn}	Weekly effort (days fished) spent by technology t, directed to depth zone z and species s in time period n
IMP_{km}	Import supply (in lbs.) by size k in month m
OTH_{km}	Other Gulf supply (in lbs.) (excluding Texas) by size k and month m
STO_{znh}	Natural stock (number of shrimp) of cohort h in depth zone z and time period n
$STOR_{km}$	Cold storage level (in lbs.) by size k and month m
TEF_{szn}	Total effort (days fished) by all vessel classes directed to species s, zone z, in time period n
TR_{km}	Product transfer, i.e., amount of product (in lbs.) of size class k sold as the next smaller size class $k + 1$ in month m

for every cohort, fishing zone, and time period. The nonlinear constraints associated with this specification greatly increase solution time using MINOS (Murtagh and Saunders) as shown in McCarl and Önal. Thus, the above nonlinear relationships (except those corresponding to the first fishing period of each cohort) are replaced by linear approximations using grid linearization, which involves a set of potential effort levels of (e_r) and stock (s_r) coupled with resultant catch (f_r) (for elaboration see Duloy and Norton).[4] An approximation variable APR_r is assigned to each grid point (e_r, s_r) and the constraint (1a) is replaced by

$$\text{(2a)} \quad CATCH = \sum_r \gamma * (e_r)^{\alpha} * (s_r)^{1-\alpha} * APR_r,$$

while *TEF* and *STO* are defined by the constraints

$$\text{(3a)} \quad TEF = \sum_r e_r * APR_r, \text{ and}$$

$$\text{(4a)} \quad STO = \sum_r s_r * APR_r,$$

where e_r and s_r equal effort and stock levels at

[4] For convenience, some subscripts are not shown in the following discussion.

grid point r. Since the same effort is applied to all shrimp cohorts, (3a) gives rise to

$$(4)\quad TEF_{szn} - \sum_r e_r * APR_{hznr} = 0 \text{ for all relevant } s, h, z, n.$$

Linear approximation also requires the additional convexity constraint:

$$(5)\quad \sum_r APR_{hznr} \le 1 \text{ for all relevant } h, z, \text{ and } n.$$

Initially, the optimal linear approximation involved nonadjacent grid points for the smallest shrimp. Referring to figure 1, given the isoquant portrayed for effort stock relationships and that effort and stock are in the ratio given by P, then the approximation should use rays 4 and 5 to generate maximum efficiency. However, when approximating the catch effort relationship in the first fishing period for each cohort, the solution used the two end rays (R_1 and R_6) which led to inefficient catch per unit. This result allowed the small shrimp to escape even though effort was applied. Simultaneously, effort was properly applied to all the coexisting larger size shrimp cohorts. Normally, fishing is expected to yield a simultaneous catch of all cohorts. Apparently, however, it was optimal to allow the small shrimp to escape so that they would be available later as larger and more valuable shrimp. Consequently, the relation (1a) is used directly (not approximated) in the first period in which a co-

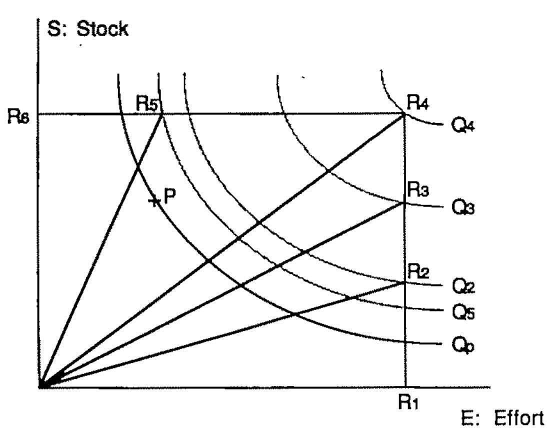


Figure 1. Proper and improper (nonadjacent) grid selection during linear approximation

hort is introduced. Therefore, the catch for the first period in which a cohort recruits is determined by

$$(6)\quad CATCH_{z\hat{n}h} - \gamma[TEF_{sz\hat{n}}]^{\alpha} * [STO_{z\hat{n}h} * (1 - 0.5 * (u_{hnz} + v_{hnz}))]^{1-\alpha} = 0$$

for all z, h, and associated $\hat{n}$. Stock is endogenously determined in all periods, except the first. There, initial stock is specified exogenously as

$$(7)\quad STO_{z\hat{n}h} = bs_{zh} \text{ for all } h.$$

The next constraint set equates current stock in period n to the stock in the previous period less catch, net migration, and less mortality:

$$(6a)\quad STO_{znh} - \{(1 - u_{hnz} - v_{hnz}) * STO_{z,n-1,h} - CATCH_{z,n-1,h} + v_{hnz} * STO_{z-1,n,h}\} = 0.$$

After linearization, the variables $CATCH$ and STO are replaced by their equivalents using (2a) and (4a) which leads to

$$(8)\sum_r s_r * APR_{hznr} - \left\{\sum_r [(1 - u_{hnz} - v_{hnz}) * s_r - f_r] * APR_{hz,n-1,r} + \sum_r v_{hnz} * s_r * APR_{h,z-1,nr}\right\} = 0 \text{ for all relevant } h, z, n,$$

while the shrimp carry-over from the first period in which the cohorts recruit is given by

$$(9)\quad \sum_r s_r * APR_{hz,\hat{n}+1,r} - \left\{STO_{z\hat{n}h} * (1 - u_{h\hat{n}z} - v_{h\hat{n}z}) - CATCH_{z\hat{n}h} + \sum_r v_{h\hat{n}z}\, s_r * APR_{h,z-1,\hat{n}+1,r}\right\} = 0$$

for all z, h, and associated $\hat{n}$. Equation (9) differs from equation (8) only in that the catch and stock variables are handled nonlinearly while they are linearized in equation (8).

The next set of constraints is a supply demand balance, requiring total demand for each size class of shrimp in any month to be no more than supply:

$$(10)\quad DEM_{km} - STOR_{k,m-1} + STOR_{km} + TR_{k+1,m} - TR_{km} - OTH_{km} - IMP_{km} - \sum_z \sum_n \sum_h w_{nh} * q_{knh} * d_{nm} * [f_r * (1 - 0.5 * (u_{hnz} + v_{hnz})) * APR_{hznr}] \le 0$$

for all m and k.

Several terms in this equation merit explanation. (a) The bracketed term will be replaced

by $CATCH_{z\hat{n}h}$ in the first period $\hat{n}$ for a cohort. (*b*) The *TR* variable depicts selling the product of a particular size category k as the next smaller size category if the price of the smaller category is favorable.[5] This downward substitution in sales insures that larger size classes have higher prices. (*c*) The *STOR* variable permits selling the product in a later period if the price differential is large enough to justify storage. The differences in these variables determine the net stock change in each month.

Total cold storage of all size classes of shrimp is limited by the available capacity:

$$(11) \qquad \sum_k STOR_{km} \leq sc \text{ for all } m.$$

The final constraints are the usual nonnegativity constraints:

$$(12) \quad DEM, OTH, IMP, EFF, STOR, TEF, CATCH, APR, STO, TR \geq 0.$$

Model Specification and Data

Two types of data are used: (*a*) observable economic data including the import supply, other Gulf supply and demand functions, ex-vessel prices, storage costs, effort costs, monthly storage capacity, and maximum available effort; and (*b*) unobservable biological data.

The linear ex-vessel demand functions are positioned using known price-quantity pairs and point elasticity estimates. For each size class, annual consumption figures and average ex-vessel prices are calculated from data obtained from the records of U.S. Department of Commerce National Marine Fisheries Service (NMFS). Other NMFS data used are cold storage holdings, non-Texas production, and imports by the month. Reported cold storage is not by size classes, but the stock composition is assumed the same as the composition of the total supply. The demand elasticities range between −1.1 to −1.5 with smallest and largest size classes being less elastic than others. These elasticities are based on the overall elasticity estimate of Doll, which is −1.42. Supply functions are positioned similarly using the observed domestic and import supplies and a point elasticity of 0.80 for all months and size classes.

Cold storage cost consists of fixed plus interest expense (computed on a 10% annual basis) on the value of the holding to the inventory. The costs per day fished are $576 and $805 per day, respectively, for the two vessel classes. The maximum fishing days for each month are 10% above the observed levels, while the storage capacity is set 10% above the maximum actual storage level during the base year.

The biological data used in the model include the number of shrimp recruited and migration and mortality rates for each species and cohort that are not statistically observable. These latter data are derived from the simulation model GBFSM (Griffin et al. 1988), which generates weekly data over the period 1963–79. The number of shrimp recruited in 1985 is obtained by running GBFSM until the total landings are close to the observed landings when the observed effort pattern in 1985 is used while keeping the rest of the data the same. The effort and landings (by species, depth, vessel class, and week) used during validation are obtained from the NMFS records. The parameters of production functions (i.e., catch/effort/stock relations) are also unobservable. The model is run using the observed effort data by varying the parameters systematically until the model results are close to the reported landings.

Model Validation

The model was validated for the base year 1985. Because effort and its distribution are optimized, validation cannot be based on comparison of the model's optimal effort with the historical effort. Instead, the actual effort data observed in the base year were imposed by setting the endogenous effort variables at the observed levels. The resulting landings are then compared with recorded landings.

The results of the validation run are presented in table 2. Total landings by species and depth closely simulate the actual data, but large deviations are shown between the size distribution of 1985 actual landings and model values for size-2 and size-3 landings. This lack of fit may result from (*a*) errors in unobservable biological data specification (which were adapted using GBFSM), (*b*) errors in the production function estimation, (*c*) errors introduced by the linear approximation procedure, (*d*) impreciseness in the data for the distribution of landings among

[5] Size classes are indexed from large to small, i.e., size-1 is the largest while size-5 is the smallest category. See table 2 for size class definitions.

Table 2. Base Model Solution and Observed 1985 Landings

	Model	Actual
	(1,000 lbs.)	
Landings by Size Classes[a]		
Size-1	4,262	4,880
Size-2	14,304	8,570
Size-3	11,085	14,792
Size-4	4,277	5,236
Size-5	8,231	8,541
Landings by Species and Depth Levels[b]		
Brown shrimp		
Depth-1	5,702	5,753
Depth-2	3,286	3,264
Depth-3	22,333	22,170
Total	31,301	31,187
White shrimp		
Depth-1	4,499	4,601
Depth-2	5,751	5,767
Depth-3	589	460
Total	10,839	10,828
Total landings	42,140	42,015

[a] Size classes, from smallest to largest, are defined in terms of head-off length L (in mm) as follows: size-5: $76.9 \leq L < 111.4$, size-4: $111.4 \leq L < 122.2$, size-3: $122.2 \leq L < 143.6$, size-2: $143.6 \leq L < 163.2$, size-1: $163.2 < L$. These correspond to the size classification in shrimp landing statistics based on counts per pound.
[b] Depth-1 refers to bays, depth-2 refers to inshore waters up to 10 fathom depth line, depth-3 refers to offshore waters beyond 10 fathom depth line.

the five size classes, and/or (*e*) the residual effects of the optimization process even though operating with constrained effort. This study largely focuses on effort and total landings by species, location, and time. In this regard, the model's performance was considered satisfactory. The size results will be discussed only in terms of changes from the base solution.

The Optimum Harvest Pattern

The model was next run without effort constraints in order to obtain the effort distribution that maximizes social welfare. The results (table 3) suggest that the Texas shrimp fishery as modeled can produce about 94% of its 1985 output (i.e., total quantity in pounds) with only 63% of the observed effort. Effort appears particularly excessive in the bays and shallow offshore waters. Both brown and white shrimp are subject to about the same degree of overfishing. Under the optimal harvest pattern, brown shrimp landings are reduced while white shrimp landings increase and bay landings are largely eliminated. Also the size distribution of landings shifts with small shrimp landings curtailed in favor of the first two large size categories.

The seasonal distribution of optimal effort differs from the observed distribution. The optimal shrimping pattern for brown shrimp shows the major season starting in July and continuing until the end of November with the major effort in October. However, actual major shrimping effort starts in May and continues until January with the highest shrimping observed in August. Therefore, the optimal solution shows a shorter (about 5-month long) major shrimping season with a later peak. For white shrimp, the optimal solution shows a major shrimping season which excludes spring. The optimal peak shrimping period, which now occurs in October, is delayed to December.

Another interesting finding is that the model shows the least brown shrimping effort in May, while July and August effort levels are low for white shrimp. This result is consistent with the timing of the currently used Texas closure regulations (closing the fishery in May and June). Thus, the results partially justify the current form of the Texas closure.

The reduced effort (and therefore cost) and the improved size distribution are socially beneficial relative to the base situation. Both consumers and producers gain (table 4). Producers receive 14.5% more producers' surplus, while consumers gain 2.8% relative to the base case. As a whole, society gains 10% more welfare as measured by social surplus (enforcement costs are not accounted for).

The model was also run with a modification in equation (6) which mandates small shrimp will be caught if effort is applied to coexisting larger shrimp. This equation is changed to an inequality ($\leq$) to allow smaller shrimp to escape if optimal. This escape can be achieved in practice by adjusting fishing net size. The results show that Texas supply is rather insensitive in terms of overall quantity landed. However, column (C) in table 4 shows considerable changes in composition with more large shrimp landings. The highest gains are made in the size-3 and size-4 landings (0.7 and 0.5 million lbs.), while the size-5 landings decline (by 1.8 million lbs.). As a result, both the value of shrimp landings and profits increase (by \$3 and \$2 million, respectively), with both producers and consumers gaining. This finding suggests consideration of a coarser mesh size.

These results can be compared with earlier re-

Table 3. The Optimum Harvest Pattern

	Effort (1,000 days)		Landing (1,000 lbs)		
	Actual	Optimal	Actual	Base	Optimal
By Species					
Brown	56.1	35.5	31,187	31,301	27,120
White	26.4	16.7	10,828	10,839	12,340
By Depth Levels					
Depth-1	14.9	5.5	10,354	10,201	7,045
Depth-2	23.6	11.5	9,031	9,037	8,730
Depth-3	43.9	35.2	22,630	22,922	23,684
By Size Class					
Size-1			4,880	4,262	7,111
Size-2			8,570	14,304	16,983
Size-3			14,792	11,085	9,187
Size-4			5,236	4,277	2,518
Size-5			8,541	8,231	3,660
Total	82.4	52.2	42,015	42,140	39,460

Table 4. Comparison of the Socioeconomic Aspects of the Base Run with the Optimal Harvesting Policy

	Base Solution (A)	Optimal Harvest (B)	Selective Effort (C)
Landings (million lbs.)			
Size-1	4.3	7.1	7.2
Size-2	14.3	17.0	17.3
Size-3	11.1	9.2	9.9
Size-4	4.3	2.5	3.0
Size-5	8.2	3.7	1.9
Total	42.2	39.5	39.2
Economic indicators (million $)			
Revenue[a]	126.0	135.0	138.0
Net income[a]	61.0	93.0	95.0
Import cost	487.0	475.0	473.0
Welfare indices[b]			
Producers' surplus[c]	100.0	112.8	113.7
Consumers' surplus	100.0	102.7	103.2
Social surplus[d]	100.0	105.0	105.5

[a] Only Texas producers are considered.
[b] Base solution index = 100.
[c] Producers surplus includes the net revenue earned by Texas producers and the surplus received by other Gulf producers (sum of areas under the associated supply functions). The surplus of importers is not included.
[d] Social surplus is defined as the sum of producers' and consumers' surplus.

sults of Texas shrimp fishery studies. Previous studies have shown biological and/or economic gains in reducing the fishing effort at least in spring and summer. Nance and Nichols found that significant gains can be obtained by shifting the shrimping effort toward fall, as occurred here. Griffin, Lacewell, and Nichols found that optimum rent accrues when the total effort is reduced by 45%, which is similar to the effort reduction here; however, they did not address seasonality. Blomo et al. (1978) derived spatial and seasonal results similar to those found here on the desirability of shifting fishing effort from inshore to offshore and from spring to summer and fall. However, they suggest increasing offshore effort by 80% to maximize benefits; while our model suggests all effort, including offshore, should be reduced.

Concluding Comments

This modeling study indicates that under the assumptions herein the Texas shrimp fishery is subject to substantial overfishing, especially during spring and summer, both in bays and shallow offshore areas. Under the optimal allocation of shrimping effort, the model shows a

reduction (6%) in overall amount of the harvest with 38% less effort. Simultaneously, the size composition changes in favor of the large size categories, while small shrimp catches decrease. Consequently, in total, both the producer and consumer groups gain under the optimal harvest pattern.

As in any modeling work, the reliability of the results depends on the realism of the data base. In this case study, critical biological data and catch/effort/stock relationships were unobservable, being drawn from a simulation model by a "best fit"-type of procedure. The approximation procedures used in the model (including linear approximation of nonlinear constraints and discrete approximation of a dynamic continuous system) may also introduce errors. To reduce these errors, shorter time periods and more grid points could be used. However, the model used here is already large, and a larger model may not be practical.[6] Therefore, the empirical results should be regarded with caution, although they seem highly plausible.

The optimum harvest policy does not consider the open access nature of this fishery since the distribution of producers' surplus between bay and offshore shrimpers is ignored. The analysis is normative rather than descriptive, assuming that a sole owner maximizes the total returns considering the future value of escaping stock. This is not the case in open access fishery since bay and offshore fishermen do not cooperate. This issue requires further analysis using different methods, such as multilevel programming.

Finally, it appears that standard policies used in the Gulf of Mexico shrimp fishery, such as closure and net size regulations, will not alleviate the overfishing problem. These types of measures encourage additional overfishing in the long run. If fishery managers seek optimum effort, then limited entry schemes would be needed, such as transferable quotas or license limitations, possibly coupled with some type of buyback mechanism. Income distribution would be an important factor in the design of such a scheme.

[Received September 1989; final revision received January 1991.]

[6] The critical parameters affecting the model size are the number of fishing zones, time periods, shrimp cohorts, species, and grid points used in linearization. These parameters are set to 3, 16, 12, 2, and 6, respectively. The model then has 1,433 constraints, 72 of which are nonlinear, and 2,911 variables, 330 of which are nonlinear appearing either in the objective function or in the constraints.

References

Anderson, L. G., A. Ben-Israel, G. Custis, and C. Sarabun. "Modeling and Simulation of Interdependent Fisheries and Optimal Effort Allocation Using Mathematical Programming." *Applied Operations Research in Fishing*, ed. K. B. Haley. New York: Plenum Press, 1981.

Blomo, V., J. P. Nichols, W. L. Griffin, and W. E. Grant. "Dynamic Modeling of the Eastern Gulf of Mexico Shrimp Fishery." *Amer. J. Agr. Econ.* 64(1982):475–83.

Blomo, V., K. Stokes, W. L. Griffin, W. E. Grant, and J. P. Nichols. "Bioeconomic Modeling of the Gulf Shrimp Fishery: An Application to Galveston Bay and Adjacent Offshore Areas." *S. J. Agr. Econ.* 10(1978):119–25.

Clark, C. W. *Mathematical Bioeconomics: The Optimum Management of Renewable Resources.* New York: John Wiley & Sons, 1976.

Doll, J. P. "An Econometric Analysis of Shrimp Ex-vessel Prices, 1950–68." *Amer. J. Agr. Econ.* 54(1972):431–40.

Duloy, J. H., and R. D. Norton. "Prices and Incomes in Linear Programming Models." *Amer. J. Agr. Econ.* 57(1975):591–600.

Grant, W. E., and W. L. Griffin. "A Bioeconomic Model of the Gulf of Mexico Shrimp Fishery." *Trans. Amer. Fisheries Soc.* 108(1979):1–13.

Griffin, W. L., J. Clark, B. A. McCarl, H. Önal, B. Wyomola, R. Sadeh, and R. B. Byrne. *User Guide for General Bioeconomic Fishery Simulation Model (GBFSM Version 2.0).* Texas A&M University, 1988.

Griffin, W. L., R. D. Lacewell, and J. P. Nichols. "Optimum Effort and Rent Distribution in the Gulf of Mexico Shrimp Fishery." *Amer. J. Agr. Econ.* 58(1976):644–51.

Griffin, W. L., J. Warren, J. Nichols, W. Grant, and C. Pardy. *The Texas Shrimp Fishery: Analysis of Six Management Alternatives Using the General Bioeconomic Simulation Model.* TAMU-SG-84-202, Texas A&M University, 1983.

Haynes, J., and S. Pascoe. *A Policy Model of the Northern Prawn Fishery.* Canberra: Australian Bureau of Agr. and Resour. Econ. Occas. Pap. No. 103, 1988.

Jones, A. C., E. F. Klima, and J. R. Poffenberger. "Effects of the 1981 Closure on Texas Shrimp Fishery." *Marine Fisheries Rev.* 44(1982):1–4.

Karp, L., A. Sadeh, and W. L. Griffin. "Cycles in Agricultural Production: The Case of Aquaculture." *Amer. J. Agr. Econ.* 68(1986):553–61.

McCarl, B. A., and H. Önal. "Linear Approximation Using MOTAD and Separable Programming: Should It Be Done?" *Amer. J. Agr. Econ.* 71(1989):158–66.

McCarl, B. A., and T. H. Spreen, "Price-Endogenous Mathematical Programming As a Tool for Sector Analysis." *Amer. J. Agr. Econ.* 62(1980):87–102.

Meuriot, E., and J. M. Gates. "Fishing Allocations and Optimal Fees: A Single and Multilevel Programming Analysis." *Amer. J. Agr. Econ.* 65(1983):711–21.

Murakowski, S. A., and J. T. Finn. "Optimal Effort Allocation Among Competing Mixed-Species Fisheries

Subject to Fishing Mortality Constraints." *Can. J. Fisheries and Aquatic Sci.* 43(1986):90–100.

Murtagh, B. A., and M. A. Saunders. *MINOS: Augmented Users Manual.* Systems Optimization Laboratory Tech. Rep. SOL 80-14, Stanford University, 1980.

Nance, J. M., and S. Nichols. *Stock Assessment for Brown, White and Pink Shrimp in the U.S. Gulf of Mexico, 1960–88.* Miami FL: National Marine Fisheries Southeast Fisheries Center, 1987.

Rothschild, B. J., and J. W. Balsiger. "A Linear Programming Solution to Salmon Management." *Fisheries Bull.* 69(1971):117–39.

Sadeh, A., H. Talpaz, D. A. Bessler, and W. L. Griffin. "Optimization of Management Plans with Short and Long Run Problems: The Case of Shrimp Production." *Eur. J. Operational Resour.* 40(1989):22–31.

Siegel, R. A., J. J. Mueller, and B. J. Rothschild. "A Linear Programming Approach to Determining Harvesting Capacity: A Multiple Species Fishery." *Fisheries Bull.* 77(1979):425–33.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. *Shrimp Statistics*, monthly publications. New Orleans, various issues 1976–88.

——. Unpublished effort data. Galveston TX, 1985.

——. Unpublished landings data. Washington DC, 1985.

Unstable Models from Incorrect Forms

Julian M. Alston and James A. Chalfant

Parametric tests for structural change are conditional on the joint hypothesis of functional form and other aspects of the model specification. This problem is often disregarded. Monte Carlo evidence using three data sets indicates that apparently innocuous specification errors can lead to substantial increases in the probability of finding structural change when it is not present in the data-generating mechanism. Significant Chow tests and autocorrelation are much more likely when the wrong functional form is used. Maximum Chow tests falsely reject stable preferences much more often than their nominal size suggests, even when the correct model is estimated.

Key words: Chow tests, meat demand, regression diagnostics, structural change.

> And [is] every failure of an economic prediction a showing that tastes have changed? Not quite. Changing tastes can invalidate a prediction, but so too can a mistaken analysis—the neglect of some other important variable, the improper formulation of the theory, clumsy statistical technique. The economist looks for these sources of failure much more often than he looks for changing tastes—simply because they have been found to be more probable than changing tastes.
>
> —G. J. Stigler, page 39

> Further, the specification error leaves no trace of its evil presence. The methods of statistics deal, quite properly, with sampling errors alone, and cannot be expected to help with others. When these others are serious, as we all believe they usually are, there is no point in continuing to talk relatively much about the (relatively small) sampling error. To do so, as economists and other quantifiers do nowadays on a massive scale, is to imitate the drunk who looks for his wallet under the lamp post because the light is better there.
>
> —D. N. McCloskey, page 162

A large and perplexing variety of diagnostic tests for model specification are available to the applied researcher (as illustrated by Beggs, for example). These tests are usually designed to detect a specific aspect of model failure, such as autocorrelation or heteroskedasticity, but they are valid for that purpose only when all other aspects of the model specification are correct. Otherwise, a rejection of the null hypothesis cannot be interpreted as anything but a rejection of the complete set of joint hypotheses underlying the model. In these circumstances, it is risky to assume that a particular factor is responsible for the results, yet such assumptions are commonplace. The question of functional form, in particular, is often ignored; and the results from model-specific diagnostic tests are used to draw inferences about economic structure without due regard to the joint hypothesis that the functional form is correct.

This type of problem is inherent in empirical economics. Economic theory is not informative about appropriate choices for functional form and other aspects of model specification. Because these choices are unavoidable, it is crucial to know their implications.

For example, a large number of recent studies have attempted to test for structural change in the demand for meats by estimating demand equations and testing their stability.[1] Mixed results have been obtained, primarily as a result of differences in specification. The weakness of

Julian M. Alston is an associate professor, Department of Agricultural Economics, University of California, Davis; James A. Chalfant is an associate professor, Department of Agricultural and Resource Economics, University of California, Berkeley.

Giannini Foundation Paper No. 973.

The authors thank Ron Bewley, Deborah Brown, Oscar Burt, Shankar Subramanian, Jim Wilen, and an anonymous referee for helpful comments on drafts, and Nancy Ottum for drawing the diagram.

[1] Papers by Chalfant and Alston, Dahlgran, and Moschini and Meilke, and the papers in the volume edited by Buse together provide a reasonably comprehensive listing of the main studies.

this approach to testing stability of demands was emphasized by Chalfant and Alston—the typical parametric test for structural change is a test of the stability of a particular functional form for demand equations, not a test of the unconditional hypothesis that consumption patterns have undergone structural change. The use of an incorrect functional form (or some other specification error) might therefore lead to a false rejection of the hypothesis of stability.

We all know that specification choices affect inferences. What is not known is the degree to which results will be sensitive to typical specification choices. For example, how likely are we to cause a false finding of structural change by choosing the wrong functional form for demand equations? A reading of the literature suggests that most practitioners are relatively unconcerned about this problem; the implicit assumption is that errors in specification, especially in relation to functional forms, are unlikely to have important implications for econometric inferences.[2]

Clearly the question is an empirical one, and the answer will depend on the particular application. The objective of this paper is to assess the effects of specification error, resulting from an incorrect functional form, on the results from typical diagnostic tests: "Chow tests" for discrete structural change and Durbin-Watson tests for "dynamics."[3] We also compare the results from using the maximum Chow test (obtained by searching across the data for the point to split the sample) with those from the conventional Chow test (the split-point is specified in advance).

To do this we conduct Monte Carlo experiments based on three familiar data sets: the General Electric data used by Zellner, the U.S. meat consumption data used by Wohlgenant and others, and the synthetic data used by Kiefer and MacKinnon and by Wales. We measure the frequency of findings of discrete structural change and autocorrelation when a set of incorrect models is estimated using data generated from a known data-generating process that contains neither structural change nor autocorrelation.

An Illustration of the Effects of Specification Error

The central idea is illustrated in figure 1. The curve D_0D_0' represents a true (stable) demand function with a constant elasticity (i.e., $\ln Q = \alpha_0 + \alpha_1 \ln P$). Prices are exogenous and quantities are measured with error, so that observed quantity and price combinations are scattered around the true demand curve in the shaded area. Suppose a linear demand equation (i.e., $Q = a_0 + a_1P$) is estimated with these data. The statistical properties of this model will depend on the curvature of the true function, the relative frequency with which the various prices are observed, and the size of the errors in measurement of quantities. As the diagram shows, the linear model (D_1D_1') will underpredict quantities for extreme values of prices and overpredict in the middle of the range. With any luck, we might detect some problems with the residuals. This might suggest that the linear functional form is incorrect, but a more typical response would be to maintain the assumption of the functional form and question its stability.

An F-test for structural change might be applied to find out whether structural change could explain the residual pattern or to test a prior hypothesis about demand shifts. The data set could be split at the midpoint of the sample to test whether a shift in the parameters (a_0 and a_1) had occurred. The nature of the price data is likely to have direct implications for the results. For example, suppose the price was high early in the sample and low late in the sample. The stable linear model is likely to be rejected in favor of a kinked demand model (such as D_2KD_2' in fig. 1), leading to the conclusion that a structural shift in demand had occurred.[4]

An alternative problem might occur when the researcher tests for the "dynamic stability" of the estimated regression. The correct model to estimate for the above case is

$$\ln Q = \alpha_0 + \alpha_1 \ln P + u.$$

[2] It is likely that some of this confidence is due to an overly optimistic belief in the ability of "flexible functional forms" to approximate unknown functional forms. Some of it may also be caused by a reluctance of authors to admit to (or of journals to publish) the results of specification searches. On the other hand, it would probably inspire more, rather than less, confidence if one could report a finding of structural change that was consistent across several alternative specifications.

[3] In keeping with customary usage, we use the term Chow test to describe the application of the usual F-test for a shift in parameters of a model. Maddala notes that this test was suggested earlier by Rao and by Kullback and Rosenblatt and suggests that Chow's test for unbiased prediction errors should be called the Chow test.

[4] The converse may also be true: that is, a functional form error could lead to a false finding of stability. For instance, this could arise when the kinked linear model in figure 1 with structural change is the true data-generating mechanism but the constant elasticity model is estimated. We thank Deborah Brown for this point. The issue of the implications of specification error for the power of tests for structural change is not dealt with in this paper.

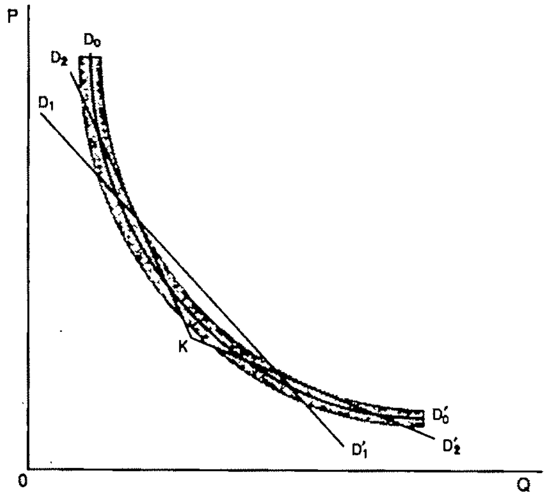


Figure 1. A Chow test in the presence of specification error

Estimating the alternative model,

$$Q = a_0 + a_1 P + v,$$

implies that

$$v = \exp(\alpha_0 + \alpha_1 \ln P + u) - (a_0 + a_1 P);$$

so the properties of v will depend on the parameters of the model and also on the exogenous variables. Any trends in P would show up as autocorrelation in the estimated residuals of the linear model, which might lead some researchers to emphasize the dynamic nature of consumption.[5] However, using an incorrect functional form is like omitting relevant explanatory variables, and correcting for apparent autocorrelation is not a good prescription for the omitted variables problem (e.g., Maddala).[6]

Clearly nonnested tests, Box-Cox type transformations, etc., will permit detection of some of these mistakes. Whenever the specification choice can be restricted to whether variables enter as levels or logarithms, that is certainly true, but usually there is no basis for assuming that truth is either linear or logarithmic. Moreover, such checks are not always performed and, in any event, they will not handle the issues that arise from the use of a particular functional form when there is no prior basis for limiting the possibilities to nested alternatives.

The Monte Carlo Approach

The experiments are designed to examine how use of the wrong model might lead to an incorrect conclusion from a diagnostic test. This requires a comparison to the correct model, so a means to generate data for Monte Carlo experiments is needed.

It is easy to generate data consistent with the assumed structure of any estimated regression model. Suppose the model $y = X\beta + \epsilon$ is estimated with a sample of size T, with ϵ assumed to be a vector drawn from $N(0, \sigma^2 I_T)$. Then new vectors y^* can be created as $y^* = X\hat{\beta} + \hat{\sigma}e$, where e is a random draw from the standard normal distribution, $\hat{\beta}$ is the sample estimate of β, and $\hat{\sigma}$ is the sample estimate of σ. A regression of y^* on the X matrix is a correctly specified model. Thus, the usual structural change test has properties that are known from the theory—using a prespecified point at which the sample is to be split and a chosen level of significance α, the Chow test will falsely indicate structural change $100{*}\alpha\%$ of the time using

$$F = \frac{[SSE_r - SSE_u]/K}{SSE_u/(T - 2K)} \sim F_{K,T-2K},$$

where SSE_r is the sum of squared residuals from the stable linear model, SSE_u is the sum of squared residuals from the compound (unstable) model, and K is the number of parameters in the stable model (when we are testing the stability hypothesis against the alternative that any of the parameters could vary).

Now suppose that the wrong functional form is estimated. Instead of y^* on X, the model is estimated with transformations of the data, such as logarithms or square roots. How often will the above test for structural change indicate that it has occurred?

We proceed as follows. First, we try single-equation models for four data sets (for General Electric investment and U.S. consumption of

[5] Alternatively, trends in P might lead to finding significant trends when time is included as a regressor to test for structural change. Alston and Chalfant (1991) show that this result can be obtained by errors in specification of functional form. Fiebig and Maasoumi analyzed the opposite case, where a trend variable is used to account for the effects of a true AR process.

[6] The joint problem of incorrect functional form and autocorrelation was first considered by Prais and Houthakker. It was considered subsequently by Savin and White in a joint Box-Cox AR(1) framework. Fiebig and Bewley provided empirical results on Savin and White. While it is clearly possible to conduct joint estimation of the autocorrelation coefficient (ρ) and the Box-Cox parameter (λ), this in no way removes the functional form problem unless it is known that the true model is of the Box-Cox class—it merely substitutes a broader class of models to be held as a joint hypothesis.

beef, pork, and poultry). For each data set, we estimate a linear model using ordinary least squares and save the predicted values. These are used (with 200 random draws of standard normals) to generate 200 vectors of the form y^* which are then used, along with transformations of the corresponding values in the X matrix, to estimate models known to be false. With the generated data, the linear model is the true model. The two false models used for most of what follows are regressions with the variables appearing as logarithms and as square roots of their original values, respectively. In addition, in some of the work, a semilog model is tried. When the linear, square root, and logarithmic models are viewed in the context of the Box-Cox transformation, the Box-Cox parameter is useful as a measure of the distance of the estimated model from the correct linear one. With this in mind a model with a Box-Cox parameter of 0.9 (i.e., a Box-Cox model that is almost linear) is included to explore the relationship between the magnitude of the specification error and its consequences.

The data from the single-equation models for meat demand do not satisfy the integrability conditions. We would expect to obtain similar results in systems of demand equations that do satisfy integrability conditions. In order to explore formally the implications of specification error in the context of systems of well-behaved demand equations, we also tried testing for structural change when an almost ideal demand system was fit to data generated from a stable linear expenditure system (LES). The approach in this case was essentially the same as that used for the single-equation models although in the demand systems we used more replications (1,000 instead of 200).

The G.E.–Westinghouse Data Set

A familiar data set from econometrics is the investment data for General Electric and Westinghouse from Grunfeld, which were obtained from Theil (p. 296). Zellner used this data set to introduce seemingly unrelated regressions. We report only the results from the G.E. component of those data. Investment was assumed to be given by

$$GEI = \beta_0 + \beta_1\, GEF + \beta_2\, GEC,$$

where GEI denotes investment by G.E., GEF denotes the firm's (lagged) market value, GEC its capital stock, and $\beta' = [\beta_0\ \beta_1\ \beta_2]$ are parameters to be estimated as $b' = [b_0\ b_1\ b_2]$.

The data were generated according to the method described earlier except that in this case we used standard normal errors without scaling by the sample estimate of σ.[7] We fit the GEI equation using OLS and saved the predicted values.[8] Then new vectors GEI^* were generated by adding the generated errors to the predicted values. Every vector so generated could be regressed on GEF and GEC; doing this a large number of times would permit us to discover that b is $N[\beta, \sigma^2(X'X)^{-1}]$, that the Durbin-Watson statistic behaves in the way tabulated, and that the probability of finding structural change with a Chow test—when none has occurred—is α.

What we can also do is fit the wrong model to these generated data sets and examine the behavior of the same statistics. The interest is not in the parameters themselves.[9] We focus on the behavior of diagnostic tests such as the F-test for structural change, the Durbin-Watson statistic, and the estimate of the first-order autocorrelation parameter ρ.

The wrong models we estimated are common alternatives:

$$(1)\quad GEI^* = b_0 + b_1 \log(GEF) + b_2 \log(GEC) \quad \text{(the semilog)}$$

$$(2)\quad \log(GEI^*) = b_0 + b_1 \log(GEF) + b_2 \log(GEC) \quad \text{(logarithmic)}$$

$$(3)\quad (GEI^*)^{0.5} = b_0 + b_1\, GEF^{0.5} + b_2\, GEC^{0.5} \quad \text{(square root)}$$

$$(4)\quad (GEI^*)^{0.9} = b_0 + b_1\, GEF^{0.9} + b_2\, GEC^{0.9} \quad (\text{Box-Cox}, \lambda = 0.9).$$

The latter three models include various Box-Cox type transformations of all of the included variables; the last would not normally be estimated as a matter of course, but it shows how small deviations from the true model, as measured by

[7] We also carried out a simulation with the errors scaled up by the estimate of the sample standard error and the incidence of false rejections of the stable model was much reduced, but the pattern across models remains the same (results are available from the authors). When we add more "noise" to the model, structural change is found less often; the specification error is less obvious.

[8] The estimates were identical to those published by Theil (p. 295) for this model with the G.E. data.

[9] White and others have examined the properties of parameter estimates when incorrect models are estimated; Kling and others have extended this to examine the implications for welfare measures.

the Box-Cox parameter, affect the performance of diagnostic tests. It seems likely that any problem induced by fitting the wrong model will worsen with an increase in the distance between the two models.

Table 1 shows the results from estimating these models using 200 replications of the *GEI** data sets, each time testing whether a structural change (a one-time shift in the parameters) had occurred at the midpoint of the sample. Since each *GEI** vector includes twenty data points, this meant that ten data points were included in each subsample. With three parameters estimated for each subset, the calculated test statistic should be compared to critical values of the F-distribution with three numerator degrees of freedom and fourteen denominator degrees of freedom. The $\alpha = .05$ and $\alpha = .01$ values for that distribution are 3.34 and 5.56, respectively.

For each of the 200 replications, we estimated the four models above using Version 6.1 of SHAZAM (White et al.). After each regression, the DIAGNOSTIC procedure was run using the CHOWTEST option, which gives calculated values of the F-test for structural change at all possible data points. Occasionally, researchers search over the sample to find the largest F-statistic, interpreted as the most likely point for structural change to have occurred (e.g., Belongia and Chalfant, Moschini and Meilke). In this part we examined only the values obtained at the midpoint, corresponding to prior knowledge of the appropriate point at which to test whether a shift in parameter values had occurred.

The results are striking. When the wrong model is estimated, the probability of detecting a structural change for these data is high. That probability increases, as expected, as the Box-Cox parameter moves away from 1, for models (2) to (4). Model (1) is not a special case of the Box-Cox model but is subject to the same problem. In short, for all but the last model, which is "close" to linear, the researcher is guaranteed of rejecting the hypothesis of no structural change, due solely to the use of the incorrect functional form. Even in this last model, the probability of a false finding of structural change is much greater than the nominal size of the test (i.e., 22% for $\alpha = 5\%$ and 8% for $\alpha = 1\%$), suggesting that even small errors in specification of functional form can have large effects on results.

A similar experiment was performed to see whether evidence of autocorrelation was induced by estimation of the incorrect functional form. The summary measures saved from each regression were the Durbin-Watson statistic and the estimated value of the first-order autocorrelation coefficient (ρ) from the OLS residuals. Summary statistics for these values are given in table 1 for the four models above.

With the exception of the last model in table 1 (the almost linear model) the first-order autocorrelation coefficients were large (averaging 0.6 or greater) and the Durbin-Watson statistics were small (generally less than 1.0). For all 200 replications of the logarithmic and semilog models, the Durbin-Watson statistic fell below the 5% critical value of $d_L = 1.10$, guaranteeing rejection of the hypothesis that $\rho = 0$. This pattern of results is not unexpected, given a priori knowledge of the functional form. In a typical setting, however, results such as these would be more likely to cause researchers to include trends or an autocorrelation correction in their model than to reconsider the functional form.

The Meats Demand Data Set

A similar experiment was performed using data on U.S. meat consumption from Wohlgenant. The results support the view that the potential is high for rejecting the hypothesis that prefer-

Table 1. Autocorrelation Tests and Chow Tests—General Electric Investment Data

Estimated Model	First-Order Autocorrelation: Durbin-Watson Statistics: Mean	Minimum	Maximum	Mean Estimated ρ	Chow Tests: Mean F	$Pr[F > F_\alpha]$: $\alpha = .05$	$\alpha = .01$
Semilog	0.26	0.21	0.34	0.78	88.81	1.00	1.00
Logarithmic	0.78	0.51	1.04	0.60	26.24	1.00	1.00
Square root	0.87	0.48	1.48	0.56	19.77	1.00	1.00
$\lambda = 0.9$	1.89	0.71	3.19	0.02	2.55	0.22	0.08

Note: There are 200 replications per model; $d_L = 1.10$, $d_U = 1.54$ (5%); $d_L = 0.86$, $d_U = 1.27$ (1%).

ences have remained stable solely due to the use of an incorrect functional form.[10]

The data set consists of annual prices and per capita quantities for four meats—beef and veal, pork, fish, and poultry—for the years 1947 to 1983. Chalfant and Alston found that these data are consistent with the generalized axiom of revealed preference (Varian), so some stable demand system could have generated them. Wohlgenant had earlier found, using a Fourier flexible form, that the shift in consumption from beef to chicken could be explained by relative prices and expenditures, with beef and chicken becoming increasingly substitutable over time.

We proceeded much as before. First, for each of the four meat types we fit a linear demand equation in which per capita consumption is a function of the prices of the four meats (deflated by the consumer price index) and real expenditures on the group of meats. Because the linear model for fish had a positive coefficient on the fish price it was excluded from the subsequent analysis. The linear models for the other three meats (including the fish price as an explanatory variable) were considered acceptable for further analysis.[11] After fitting the linear demand equation for each good (beef, pork, and poultry), we saved the predicted values and, as described earlier, generated 200 new data sets consistent with the linear demand model by adding normally distributed errors. These data sets were then used to estimate the alternative models of interest. The alternative models were defined maintaining the assumption that per capita consumption of each meat is a function of real prices of the four meats and group expenditure.

For the Chow test part of the exercise, we estimated four models: the correct linear model, a logarithmic demand equation, an intermediate case where square roots instead of logarithms were used to transform the data, and a single-equation version of the almost ideal demand system (Deaton and Muellbauer, Alston and Chalfant 1987).[12] For the latter, a budget share was constructed using the calculated Q^* values and actual price and expenditure data. For each regression, we again obtained the output from the CHOWTEST procedure in SHAZAM. This time, we saved not only the values at the sample midpoint, but we searched over all possible points to split the sample and saved the maximum value of the Chow test.

Table 2 provides the results. For beef and poultry the results of specification error for the mid-sample Chow test are particularly dramatic. While they are less so for pork, there remains an increase in the probability of false rejection of the stable preferences hypothesis due to the use of an incorrect functional form.

Consider the results for beef. When the true (linear) model is estimated, a significant structural change is found with a frequency that is consistent with the theory (7% when $\alpha = 5\%$; 0% when $\alpha = 1\%$). A similar pattern is found with the other two meats (false rejections occur in about α% of cases). In the models of the Box-Cox type, as the specification error becomes greater (i.e., as the Box-Cox parameter, λ, moves further from 1), the frequency of false rejections rises. With the square root model ($\lambda = 0.5$) structural change is found in 22% of cases using a 5% test; with the logarithmic model ($\lambda = 0$) it is found in 75% of cases. The results for the almost ideal model are similar to those from the logarithmic model. With these last two specifications, a false rejection of stable preferences for beef, caused entirely by the use of the wrong functional form, is highly likely to occur.

The lower half of table 2 shows the results from using the maximum Chow test, obtained by searching across the data for the maximum F-statistic for the test of stable preferences instead of using a predetermined point to split the data. As expected, in every model this test found structural change much more often than the conventional Chow test. Even when the true (linear) model was estimated for beef, this test found a significant structural change in 35% of cases using a 5% test and 6% of cases using a 1% test. This pattern of results is repeated with the other meats. It suggests that a much more stringent

[10] Many have acknowledged the difficulty in simultaneously estimating the nature of demands and detecting shifts in their structure. While some evidence exists on the performance of flexible functional forms as approximations (and therefore incorrect specifications), it is either of the Monte Carlo variety or has been obtained in other contexts. In any event, this work has usually focused on the accurate estimation of elasticities and has generally not examined specification tests.

[11] This is not to say that they are accurate representations of the true demand system that generated the data. Rather, they are acceptable to use as a starting point for the Monte Carlo simulations in which they are the true data-generating process.

[12] In this part, the expenditure share for each meat was regressed against the logarithms of prices and expenditures on the four meat types with all of the monetary variables deflated by the consumer price index. This is similar to the almost ideal demand model (see below), differing only in that the consumer price index is used instead of the almost ideal demand system price index (or Stone's price index).

Table 2. Chow Tests Using U.S. Meat Consumption Data: Pr[$F > F_\alpha$]

Estimated Model	Beef		Pork		Poultry	
	α = .05	α = .01	α = .05	α = .01	α = .05	α = .01
			Chow Tests at the Midpoint of Data			
Linear	0.07	0.00	0.05	0.00	0.06	0.01
Square root	0.22	0.07	0.05	0.00	0.25	0.09
Logarithmic	0.75	0.41	0.10	0.01	0.80	0.47
Almost ideal	0.69	0.35	0.20	0.03	0.76	0.44
			Maximum Chow Tests			
Linear	0.35	0.06	0.31	0.06	0.36	0.11
Square root	0.73	0.43	0.38	0.08	0.80	0.47
Logarithmic	1.00	0.97	0.50	0.17	0.99	0.96
Almost ideal	1.00	0.87	0.67	0.30	1.00	0.96

Note: There are 200 replications per model.

nominal rejection criterion is required to obtain a true 5% test. For example, using a nominal criterion of 1% is close to a 5% test for beef and pork but not so for poultry.[13]

The results for pork are less alarming. In terms of the frequency of false rejections using a 5% test, the square root model does as well as the true model, the logarithmic model is a little worse (10%), and the almost ideal demand model is worse still (20%). However, the 5% maximum Chow tests find significant structural change in over 30% of cases with the true model, and in up to 67% of cases with the almost ideal model.

The results for poultry follow the same pattern as for beef, but with higher frequencies of false rejections of stable preferences. Unless the true (linear) model is used, structural change is likely to be found with these data using these functional forms.

Table 3 contains the results of tests for autocorrelation in the meat consumption models. The tests suggest that specification error may have induced some autocorrelation in the equations for poultry and beef. Autocorrelation seems unimportant in the pork equations.

The results varied somewhat across the three meats, even though all three demand equations were estimated with the same explanatory variables. Recall that concern over the behavior of the Chow test under specification error was motivated by the existence of trends in the data (see fig. 1). Pork consumption depends less on the more trended data (the prices of beef and chicken, along with expenditures) than do beef and chicken consumption. This helps to explain why the incorrect models do not perform substantially worse than the correct ones for pork. Analytic results might shed more light on this, but it is interesting that beef and chicken, where most discussion of structural change has centered, are the two meats that are the most sensitive to the functional form choice.

The behavior of the maximum Chow tests is of concern even when there are no trends in the data, however. To illustrate this, we generated 250 vectors of length 30 of standard normals to set $y = 0 + \epsilon$ where $\epsilon \sim N(0, I_{30})$. Regressing y on an intercept yields an estimate $b \sim N(0, 1/30)$ that should exhibit structural change only α% of the time. The maximum Chow test was significant at the 5% level in 36.8% of our replications. This suggests a large size correction and a very conservative interpretation of the maximum Chow test in all applications, with or without trends.

Structural Change in Demand Systems

The single-equation results above are sufficient to cause concern when testing for structural change. But do these results hold in the context of a demand system? There is no reason to expect the sensitivity of test results to specification errors to depend on not having an integrable demand model; after all, the same results hold in the G.E. investment case, and the artificial data we generated could have applied to any model. Still, it is worth examining whether a system of demand equations is less sensitive to the problem.

[13] Since the test statistic obtained is the maximum F-value, one could conceivably find F_α to solve $Pr[F_{MAX} > F_\alpha] = \alpha$, but the usual formula for the p.d.f. of an order statistic will not apply because the individual F-values are clearly not independent random variables.

Table 3. Autocorrelation Tests—U.S. Meat Consumption Data

Estimated Model	Durbin-Watson Statistics Mean	Minimum	Maximum	Mean Estimated ρ
Beef				
Square root	2.00	1.25	2.91	−0.02
Logarithmic	1.59	0.89	2.56	0.19
Almost ideal	1.64	0.94	2.59	0.17
Pork				
Square root	2.18	1.40	2.92	−0.11
Logarithmic	2.12	1.21	2.82	−0.08
Almost ideal	2.02	1.05	2.78	−0.03
Poultry				
Square root	1.99	1.15	2.83	−0.04
Logarithmic	1.48	0.66	2.34	0.17
Almost ideal	1.52	0.69	2.37	0.16

Note: There are 200 replications per model; $d_L = 1.19$, $d_U = 1.80$ (5%); $d_L = 1.00$, $d_U = 1.59$ (1%).

We considered a simple data-generating mechanism that has been used previously in Monte Carlo studies of demand systems by Kiefer and MacKinnon and by Wales. Kiefer and MacKinnon primarily were interested in the small-sample properties of demand system estimates, although they did consider how the models performed when they were estimated using data generated from another model. Their primary interest was in the behavior of estimates, rather than in the behavior of hypothesis tests. Their findings were not at all encouraging for the case where the wrong model is estimated.

Wales examined the behavior of the likelihood-ratio test statistic when used to test true hypotheses; he generated data from the linear expenditure system and studied the likelihood-ratio test for structural change. We made use of the data-generating mechanism used by Wales, who had adopted the one from Kiefer and MacKinnon with only slight modification. Briefly, the setup is as follows. The linear expenditure system is the system of share equations that arises from Stone-Geary-type preferences:

$$S_i = \frac{P_i X_i}{y} = \frac{P_i b_i}{y} + a_i\left(1 - \sum_{k=1}^{n} \frac{P_k b_k}{y}\right) + e_i.$$

The b_i parameters are interpreted as precommitted or subsistence quantities of the goods consumed, denoted by X_i, while a_i denotes the marginal budget share of good i. Hence, budget shares are a linear function of the supernumerary income, the amount of income that remains after the precommitted quantities have been purchased. As is well known, the LES satisfies all of the restrictions from consumer theory (provided that the a_i's are positive) because it is derived from well-behaved preferences.

Wales generated budget shares using the data for prices and income given in the appendix of Kiefer and MacKinnon's paper with the parameter vectors chosen to be $a = [0.2\ 0.4\ 0.4]'$ and $b = [0.2\ 0.1\ 0.3]'$. The prices and income generated by Kiefer and MacKinnon consist of forty observations that they considered to be consistent with the sort of data typically encountered—trends in relative prices and income.[14]

With data for prices and income and the assumed parameter values, it is possible to generate a series of predicted quantities for three goods over forty observations; data sets with a stochastic component can be generated by appending an error term. Following Kiefer and MacKinnon, and Wales, error terms were generated to exhibit timewise independence but contemporaneous correlations by generating vectors of $N(0, 1)$ random varibles and transforming them to have the covariance matrix

$$\Sigma = \begin{pmatrix} 0.000036 & -0.000025 \\ -0.000025 & 0.000049 \end{pmatrix}.$$

Errors for the first two equations were generated in this fashion and errors for the third equation were generated as $e_3 = -(e_1 + e_2)$ so that the data would satisfy adding-up, etc., by construc-

[14] This is also the sort of behavior that, in the single-equation context, leads to unreliable structural change tests under specification errors. These and other testing problems are likely to be exacerbated in the event that trends in the data, when coupled with specification error, lead to nonnormal distributions.

tion. We generated 1,000 replications of linear-expenditure system data in this manner.

First we fit the correct (LES) model to these data and tested for structural change by allowing every parameter to shift from θ to θ', between observations twenty and twenty-one, as follows:

$$\theta' = \theta + \delta^* D,$$

where D is 0 for the first twenty observations and 1 thereafter. Under the assumption that the parameters in Σ are unknown but constant across the subsamples, we tested structural change in the LES by testing whether all five δ parameters are simultaneously zero using a likelihood ratio test.[15] Then we performed the same test with an incorrect model, the almost ideal demand system of Deaton and Muellbauer:[16] the dependent variables remain budget shares, but the share equations are of the form

$$S_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{y}{P}\right).$$

As is customary, we approximated the price index, P, with Stone's geometric price index (e.g., Deaton and Muellbauer).

Concerns over the behavior of the likelihood-ratio test for structural change and the use of an estimated, rather than a known covariance matrix, have been raised in several papers. Laitinen first showed that statistical tests of homogeneity were biased toward rejection, and several papers have since shown that the problem is pervasive and holds for other restrictions and for the various approaches to testing (Wald, likelihood ratio, and Lagrange multiplier tests); several of these studies are reviewed in Theil and Clements. For that reason, we examined the behavior of the tests when the true LES model is estimated as well as when the misspecified almost ideal demand system is tried. This allows us to determine the extent to which a bias toward (or away from) rejection of hypotheses results from the behavior of the test statistic itself and the extent to which specification error has influenced its performance.

The results indicated a small amount of bias toward rejection of true hypotheses, consistent with Wales, Laitinen, and other previous studies, even when the correct model was estimated. In 1,000 replications, the likelihood-ratio test was significant in 96 cases (rather than 50) at the 5% level and in 18 cases (rather than 10) at the 1% level. Thus, there is some justification for concern over the behavior of test statistics—at both the 5% and 1% levels, the frequency of rejection was roughly twice the nominal size of the test—and one might want to adjust the rejection region along the lines suggested by Wales and others.

When we estimated the almost ideal demand system using the same data, the rejection probabilities increased substantially, consistent with our single-equation results above. Using a 5% critical value, the stability of the parameters was rejected in nearly two-thirds of the replications (634 of 1,000 replications, a frequency of 63.4% rather than 5%) and the proportion of rejections fell only to 38.6% (386 of 1,000 replications) when the 1% value was used. Functional form errors clearly are primarily responsible for these high frequencies of false rejections. The tendency of the likelihood ratio test to overreject (on the order of twice as often as the nominal size would indicate) cannot account for these high frequencies of false rejections, and size corrections would not correct the problem.[17]

These results reinforce the previous conclusions. When a demand system is estimated using data that were generated by another model, the probability of false structural change conclusions is quite high. This is so, even when both the data-generating mechanism and the estimated model are perfectly consistent with re-

[15] Wales found that the likelihood-ratio test was biased toward rejection of the true null hypothesis of stable parameter values when the sample was split into equal subsamples to test the hypothesis that all of the LES parameters were constant. He performed the test by two separate estimations, in which the elements in the covariance matrix as well as the a_i's and b_i's were permitted to vary. He notes (p. 219) that an alternative test would be to maintain the equality of the covariance parameters between the two subsamples and test only the hypothesis that the LES parameters are the same: "This is not the test generally used by economists in testing for structural change, although if only the structural parameters are of interest then it is the one that should be used." It seems to us that this is the more common approach in testing structural change in meats demand; in one system, trends or dummy variables for slope/intercept shifts are introduced and then the restriction to zero values for the coefficients of the added terms is tested (e.g., Moschini and Meilke, Alston and Chalfant 1991).

[16] The almost ideal model does not reduce to the LES as a special case, except when the b_i parameters are all zero. In that special case the LES reduces to Cobb-Douglas preferences which is also a special case of the almost ideal (all parameters except the α_i's would be zero).

[17] Wald tests are more likely to reject than likelihood ratio tests (e.g., Berndt and Savin). We checked the extent to which this was true when the LES and almost ideal demand models were fit to the data generated from the LES. When the true (LES) model was estimated, the Wald test was worse than the likelihood ratio test (22.5% of our 1,000 replications had Wald χ^2 statistics above the 5% critical value and 12.3% were significant at the 1% level). When the false (almost ideal) model was estimated, the Wald test rejected slightly more often than the likelihood ratio test (68% at the 5% level and 47.9% at the 1% level). Thus, even when the right model is estimated, the Wald test should be used with caution.

strictions from the theory and the stability hypothesis. These results also show that the use of a flexible functional form (the almost ideal demand system) does not offer any protection from this misspecification bias.

Conclusion

That specification choices affect results is well known but largely treated as a theoretical nuisance without much practical relevance. The results in this paper show that it is of great practical importance: typical specification choices made in the ordinary ways can have profound effects on the results from diagnostic tests for structural change. In our examples, the use of incorrect functional forms led to remarkably high frequencies of incorrect findings of structural change. The results reinforce the prior notion that the behavior of the exogenous variables helps determine the consequences of specification error. Similar results can be expected to occur with other data sets, other specification errors, and other diagnostic tests.

In one sense, at least, these results are encouraging. In the cases analyzed, the diagnostic tests do reject the misspecified models in most instances, usually comprehensively. Thus, the value of using these diagnostic tests as checks for specification error is reinforced. What is thrown into question is the subsequent step of drawing specific inferences from the results. Without additional information, the only valid conclusion is to reject the complete set of joint hypotheses underlying the model. The test indicates only that something is wrong.

These results also suggest that the maximum Chow test ought to be used with extreme caution. As would be expected, this test has a much higher probability of Type I error than the nominal size suggests. This frequency of false indications of structural change is related to the characteristics of the data and the model, and the actual size of this type of test is unpredictable in a practical setting. In the absence of analytic results, to interpret the maximum Chow test in any other context, it would be necessary to carry out a Monte Carlo experiment as we did.

Even using the conventional Chow test, the frequency of false rejections was high—100% in many cases. This was alarming since, in one sense, the specification problem that we considered was relatively simple. In the case of meat demand, for instance, we knew the relevant explanatory variables but (acted as if) we did not know that the correct functional form was linear. In the simulations, we considered only the implications of inappropriate transformations of the data; for instance, the implications of omitting the expenditure variable or the price of pork from the beef equation were not considered. This latter type of specification error might be more serious than the error of functional form in some settings.

What advice can we offer practitioners based on these results? Diagnostic tests of regression models can be used legitimately only to detect an incorrect specification; they are not informative about the specific cause of the problem or the cure. Testing for structural change can be very sensitive to specification choices. The problem of the joint hypothesis of functional form (and other aspects of model specification) is inherent and largely inescapable. The best advice is to be conscious of the problem and to try to minimize its importance by (*a*) using relatively flexible functional forms (e.g., Wohlgenant, Chalfant), (*b*) testing for sensitivity of results to functional form (e.g., Murray), and (*c*) being conservative in drawing implications from results that may be sensitive to functional form or other joint hypotheses, especially when those tests involve some search as with the maximum Chow tests.

[Received May 1990; final revision received December 1990.]

References

Alston, J. M., and J. A. Chalfant. "Can We Take the Con Out of Meat Demand Studies?" *West. J. Agr. Econ.* 16(1991):36–48.

——. "Weak Separability and a Test for the Specification of Income in Demand Models with an Application to the Demand for Meat in Australia." *Aust. J. Agr. Econ.* 31(1987):1–15.

Beggs, J. "Diagnostic Testing in Applied Econometrics." *Econ. Rcd.* 64(1988):81–101.

Belongia, M., and J. Chalfant. "The Changing Empirical Definition of Money: Estimates from a Model of the Demand for Money Substitutes." *J. Polit. Econ.* 97(1989):387–97.

Berndt, E. R., and N. E. Savin. "Conflict Among Criteria for Testing Hypotheses in the Multivariate Regression Model." *Econometrica* 45(1977):1263–78.

Buse, R. C., ed. *The Economics of Meat Demand.* Proceedings of a conference held 20–21 Oct. 1986, Charleston SC.

Chalfant, J. A. "A Globally Flexible Almost Ideal Demand System." *J. Bus. and Econ. Statist.* 5(1987):233–42.

Chalfant, J. A., and J. M. Alston. "Accounting for Changes in Tastes." *J. Polit. Econ.* 96(1988):391–410.

Chow, G. C. "Tests of Equality Between Substets of Coef-

ficients in Two Linear Regression Models." *Econometrica* 28(1960):591–605.

Deaton, A. S., and J. Muellbauer "An Almost Ideal Demand System." *Amer. Econ. Rev.* 70(1980):312–26.

Dahlgran, R. A. "Changing Meat Demand Structure in the United States: Evidence from a Price Flexibility Analysis." *N. Cent. J. Agr. Econ.* 10(1988):165–76.

Fiebig, D. G., and R. Bewley. "International Telecommunications Forecasting: An Investigation of Alternative Functional Forms." *Appl. Econ.* 19(1987):949–60.

Fiebig, D. G., and E. Maasoumi. "Specification Analysis in Dynamic Models." *J. Bus. and Econ. Statist.* 8(1990):443–51.

Grunfeld, Y. "The Determinants of Corporate Investment." Ph.D. thesis, University of Chicago, 1958.

Kiefer, N. M., and J. G. MacKinnon. "Small Sample Properties of Demand System Estimates" *Studies in Nonlinear Estimation*, ed. S. M. Goldfeld and R. E. Quandt. New York: Ballinger Publishing Co., 1976.

Kling, C. L. "The Importance of Functional Form in the Estimation of Welfare." *West. J. Agr. Econ.* 14 (1989):168–74.

Kullback, S., and H. M. Rosenblatt. "On the Analysis of Multiple Regression in *k* Categories." *Biometrica* 44(1957):67–83.

Laitinen, K. "Why Is Demand Homogeneity So Often Rejected?" *Econ. Letters* 1(1978):187–91.

Maddala, G. S. *An Introduction to Econometrics*. New York: Macmillan Publishing Co., 1988.

McCloskey, D. N. *The Rhetoric of Economics*. Madison: University of Wisconsin Press, 1985.

Moschini, G., and K. D. Meilke. "Modeling the Pattern of Structural Change in U.S. Meat Demand." *Amer. J. Agr. Econ.* 71(1989):253–61.

Murray, J. "Retail Demand for Meat in Australia: A Utility Theory Approach." *Econ. Rcd.* 60(1984):45–56.

Prais, S. J., and H. S. Houthakker. *The Analysis of Family Budgets*, 2nd ed. Cambridge: Cambridge University Press, 1971.

Rao, C. R. *Advanced Statistical Methods in Biometric Research*. New York: John Wiley & Sons, 1952.

Savin, N. E., and K. J. White. "Estimation and Testing for Functional Form and Autocorrelation: A Simultaneous Approach." *J. Econometrics* 8(1978):1–12.

Stigler, G. J. *The Theory of Price*, 3rd ed. New York: Macmillan Co., 1966.

Theil, H. *Principles of Econometrics*. New York: John Wiley & Sons, 1971.

Theil, H., and K. W. Clements. *Applied Demand Analysis: Results from System-Wide Approaches*. Cambridge MA: Ballinger Publishing Co., 1987.

Varian, H. "The Nonparametric Approach to Demand Analysis." *Econometrica* 52(1982):945–73.

Wales, T. J. "A Note on Likelihood Ratio Tests of Functional Form and Structural Change in Demand Systems." *Econ. Letters* 14(1984):213–20.

White, H. "Using Least Squares to Approximate Unknown Regression Functions." *Int. Econ. Rev.* 21(1980):149–70.

White, K. J., S. A. Haun, N. G. Horsman, and S. Donna Wong. *SHAZAM: Econometrics Computer Program Version 6.1—Users Reference Manual*. New York: McGraw-Hill Book Co., 1988.

Wohlgenant, M. K. "Estimating Cross Elasticities of Demand for Beef." *West. J. Agr. Econ.* 10(1985):322–29.

Zellner, A. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias." *J. Amer. Statist. Assoc.* 57(1962):348–68.

Estimating Interrelated Demands for Meats Using New Measures for Ground and Table Cut Beef

Gary. W. Brester and Michael K. Wohlgenant

Two systems of demand equations for meats are estimated using traditional and new measures of ground and table cut beef. The choice of disaggregation has a significant impact on estimated demand elasticities for hamburger and table cuts. A multivariate version of the P_E-test is used as a nonnested test of the alternative specifications. The P_E-test is an appropriate nonnested specification test when the models in question have different (but related) dependent variables. The P_E-test rejects the nonfed beef model specification but does not reject the ground beef model, which uses the new measures of ground and table cut beef.

Key words: ground beef, meat demand, nonnested hypothesis test, table cut beef.

Numerous studies have estimated consumer price elasticities of demand for food using systems of demand equations. The advantages of using a system approach versus a single-equation methodology have been well documented (Barten 1977). Generally, such studies have aggregated food commodities into relatively broad categories for parsimonious estimation. In at least some cases, however, one would expect demand elasticities to vary significantly for the disaggregated components of the broader food categories. For example, Eales and Unnevehr discuss how disaggregation of composite meat groups into component subgroups allows for the identification of sources of structural change in meat demand. Their motivation stems from the idea that an individual subgroup may be distinct from the aggregate commodity and, thus, may have a significantly different elasticity.

Researchers of beef demand have often used this same motivation for disaggregating beef consumption into at least two subgroups. It seems intuitive to consider the demand for ground beef separate from the demand for table cut beef. Not only are the two commodities significantly different from one another from a consumption perspective, but they are, in general, produced from different types of beef animals. Freebairn and Rausser note that changes in agricultural policy regarding beef import quotas may cause asymmetric impacts on firms that produce beef calves versus those firms that produce fattened beef cattle. In addition, Wohlgenant suggests that ground beef may be a better substitute for poultry products than are table cuts of beef. Consequently, aggregate beef demand may be affected by the relative composition of the supply of beef. Finally, the dramatic growth in the fast food industry is based on meals which contain ground beef.

Traditionally, researchers have used the production of nonfed beef (i.e., bulls, cull cows, grass-fattened steers and heifers) and fed beef (i.e., grain-fattened cattle) as proxies for hamburger and table cut beef consumption, respectively (e.g., Arzac and Wilkinson, Brester and Marsh, Eales and Unnevehr, Wohlgenant).[1] Beef consumption, however, is more properly characterized as a combination of the consumption

Gary Brester is an assistant professor, Department of Agricultural Economics, Kansas State University, and Michael Wohlgenant is a professor, Department of Agricultural and Resource Economics, North Carolina State University.

The authors would like to thank Jim Chalfant, V. Kerry Smith, A. Ronald Gallant, Barry Goodwin, Ted Schroeder, Jim Eales, and the Western Livestock Marketing Information Project for their helpful comments and suggestions.

[1] Throughout this paper the terms "production" and "consumption" are often used without distinction. This use is intentional because all of the quantity data examined in this article are derived directly from wholesale production data. These data are often referred to as disappearance data and are derived by adjusting wholesale carcass-weight meat production by imports, exports, and beginning and ending stocks. Then, the data are further altered to reflect retail-weight equivalent units under the assumption of a fixed proportions processing technology. Thus, production data are indeed directly used as proxies for consumption (Chalfant and Alston, Nelson and Duewer).

of hamburger and table cut beef products. Because some nonfed beef is often processed into steaks and roasts and portions of fed beef carcasses are generally processed into hamburger, the use of nonfed and fed beef data as proxies for ground and table cut beef consumption may be inappropriate.

The purposes of this paper are twofold. The first is to introduce new data which may more accurately reflect the beef market. The effects of these new data are analyzed in terms of their impacts on estimated demand elasticities for meats in a demand systems model. The second purpose is to present a multivariate version of the P_E-test as a nonnested model specification test in which the dependent variables between the models are different.

Data Development

Estimates of the per capita consumption of fed beef are based on the number of fed steers and heifers slaughtered annually and their average dressed weights. Multiplication of these components yields carcass-weight fed beef production which is subsequently converted to a per capita retail-weight equivalent. The difference between the above estimate of fed beef production and total beef and veal consumption, the latter of which is calculated by the U.S. Department of Agriculture (USDA), is designated as per capita nonfed beef consumption. This procedure closely follows that of Wohlgenant with the only difference being the methodology employed in the estimation of the average dressed weights of fed steers and fed heifers. For this study, we follow the procedure used by the Western Livestock Marketing Information Project (WLMIP). The per capita nonfed, fed, and total beef data are presented in the appendix.

The WLMIP reports estimates of ground and processed beef on an annual basis for the years 1970 to the present. They essentially use their own commercial production figures by class of beef animal and the beef and veal import numbers reported by the USDA. The WLMIP assumes that the following fixed proportions of ground beef are obtained from each class of beef animal: cows, 90%; bulls, 100%; fed cattle, 25%; nonfed cattle, 45%; imports, 80%. These percentages are assumed to be time invariant and are used to estimate carcass-weight production of ground beef. Estimates of ground beef production are then converted to a per capita retail-weight equivalent.

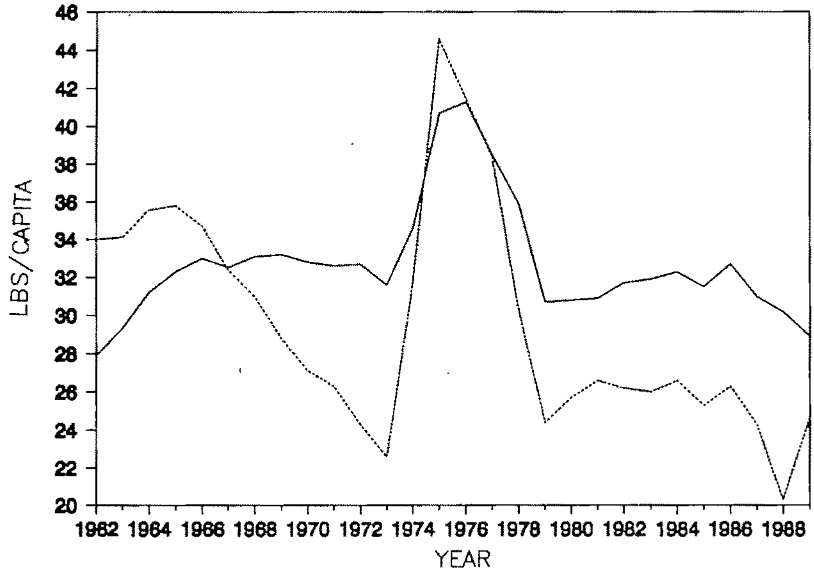
The above procedure imposes the unrealistic assumption that fixed proportions of ground beef are produced from each type of animal. It seems more appropriate to assume that the proportion of ground beef obtained from each type of carcass responds to economic factors. However, since the WLMIP data on ground beef production are readily accessible to researchers, it is likely that future studies of beef demand will use these data rather than the traditional approach of using nonfed beef production as a proxy for ground beef production. While the procedures used by the WLMIP to develop the ground beef data are admittedly not perfect, the methodology is an improvement over the traditional estimates of ground beef production (i.e., using estimates of nonfed beef production as a proxy) in that their approach explicitly recognizes that some ground beef is produced from fed carcasses and some table cut beef is produced from nonfed carcasses.

We use the WLMIP procedures described above to extend the ground beef production series for the period 1962–89. The ground and table cut beef data are reported in the appendix. A further extension of the series to earlier time periods is not possible because some of the data required for the derivation of the ground beef series were not gathered prior to 1962. The estimated per capita production of ground beef obtained from the above procedure is then subtracted from the annual per capita consumption of all beef and veal (on a retail-weight basis) as reported by the USDA (1990) to obtain the annual consumption of table cut beef on a per capita basis.

Both nonfed and fed beef consumption, as well as ground and table cut beef consumption, total to the same amount (i.e., total beef consumption as derived by the USDA from disappearance data). Consequently, the differences between the series are merely a function of data construction. Both the nonfed and fed beef data have a larger variance than the ground and table cut beef data. The upper graph of figure 1 shows the relationship over time between the nonfed and ground beef data. The lower graph illustrates the relationship between the fed beef and table cut beef data.

The Rotterdam Model

The absolute price version of the Rotterdam model is used to evaluate the alternative measures of beef consumption. This specification is



Ground beef—solid line
Nonfed beef—dotted line

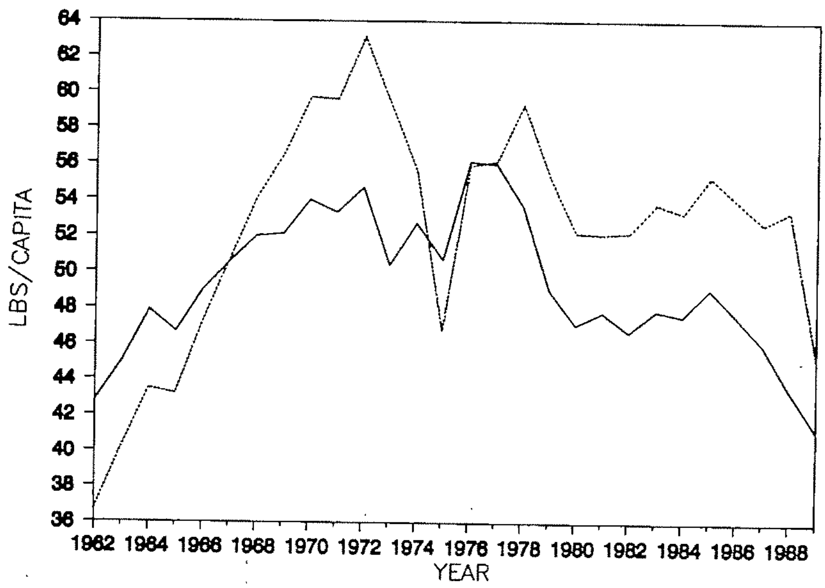


Table cut beef—solid line
Fed beef—dotted line

Figure 1. Comparison of per capita consumption of ground beef to nonfed beef and table cut beef to fed beef, 1962–89

chosen because it is based on consumer demand theory (i.e., the model is developed by totally differentiating ordinary demand equations). In addition, the model is linear in parameters and is at least as flexible a functional form as the translog, miniflex Laurent, and AIDS models (Mountain). A detailed development of the Rotterdam model is provided by Theil (1980). The estimable log differential form for discrete time periods of each of the n demand equations in the system is given by

$$(1)\quad \bar{W}_{it}\Delta\ln Q_{it} = \Phi_i + \Gamma_i\Delta\ln\bar{X}_t + \sum_{j=1}^{J}\delta_{ij}\Delta\ln P_{jt} + U_{it} \quad i = 1, 2, \ldots, n,$$

where

$$\bar{W}_{it} = 1/2(W_{it} + W_{it-1}),$$

$$\Delta\ln\bar{X}_t = \Delta\ln X_t - \sum_{i=1}^{n} \bar{W}_{it}\Delta\ln P_{it},$$

and W_i are the expenditure share weights of the ith meat, P_j are retail prices of each meat commodity and one aggregate nonmeat commodity,[2] Q_i are per capita constant dollar expenditures on each meat commodity and one nonmeat commodity, X represents per capita total personal consumption expenditures, and U_{it} is a timewise independent error term that is contemporaneously correlated across the n equations.

One of the n equations can be deleted from the system for purposes of estimation because of the following parametric restrictions:

$$(2) \qquad \sum_{i=1}^{n} \Gamma_i = 1; \quad \sum_{j=1}^{J} \delta_{ij} = 0.$$

The restrictions impose adding up and homogeneity, respectively, across the demand system.

Econometric Results for the Two Sets of Data

Prior to the econometric estimation of the systems of demand equations, both sets of data were subjected to a nonparametric test (Varian's *NONPAR* computer program) to determine if the data violate the general axioms of revealed preference (GARP). Violations would indicate that the data are not consistent with a stable set of preferences. No violations were encountered which agrees with Chalfant and Alston's results for disaggregated meat commodities.

Two meat demand systems are estimated using the absolute price version of the Rotterdam model to evaluate the consequences of the alternative measures of beef consumption. The first system (hereafter referred to as the "nonfed beef system") estimates the demand for nonfed beef, fed beef, pork, poultry, and nonmeats.[3] The second system employs new measures of ground beef and table cut beef as the components of beef demand and will be referred to as the "ground beef system." Both models assume that meat products are weakly separable from other food and nonfood commodities. The inclusion of the nonmeat equation (and the use of per capita total personal consumption expenditures as the income variable) implies that the elasticity estimates derived from the model are unconditional elasticities.

Each of the meat demand systems is estimated using the iterated seemingly unrelated regressions (ITSUR) option of the SYSNLIN procedure in SAS. The parameter estimates obtained by using ITSUR converge to their maximum likelihood values if the error terms follow a multivariate normal distribution (Judge et al.) and are invariant to the choice of the deleted equation (Barten 1969). The nonmeat equation in each model is deleted for estimation purposes. The parameter estimates for each deleted equation are recoverable via the restrictions imposed by equation (2). Definitions of the variables used in this paper are presented in table 1. Symmetry and homogeneity of degree zero in prices and income are imposed on both models.

The estimated regression coefficients for the nonfed beef system (with homogeneity and symmetry imposed) are presented in the upper portion of table 2.[4] Most of the coefficients are significant at the 0.05 level.[5] Curvature restrictions are met in that the substitution matrix is negative semidefinite. Nonfed beef appears to be an inferior good. Fed beef is a complementary good with both pork and poultry, which does not conform to a priori expectations. Neither of the two estimates, however, are significantly different from zero. The intercept terms of the Rotterdam model show trend effects in consumption, if present, for each of the meat com-

---

[2] The Rotterdam model can be estimated using either quantities or constant dollar expenditures as dependent variables. In this study, constant dollar expenditures for each commodity are obtained by multiplying quantity data by 1967 retail prices. Christensen and Manser use constant dollar expenditures as a means of aggregating component meat types. We use constant dollar expenditures to facilitate the calculation of expenditure share weights since the price data are reported as indices.

[3] The use of the term "nonmeats" is a misnomer. The variable actually represents all other consumption items except beef, pork, and poultry. Consequently, some meats are included in the nonmeat equation (e.g., fish, mutton, and purchased wild game).

[4] While the Durbin-Watson (D-W) statistics have unknown distributions in multivariate models, *SYSNLIN* calculates a D-W for each of the equations in the system. None of the D-W statistics suggest the presence of serial correlation. The R-square statistics for the nonfed, fed, pork, and poultry equations are 0.59, 0.52, 0.84, and 0.49, respectively.

[5] A reviewer expressed concern regarding the number of degrees of freedom in each of the demand systems noting that there are only 27 observations with which to estimate 18 parameters. However, as Theil (1971, p. 301) notes, "the justification of the joint GLS method is based on the assumption of a large number of observations—for which such corrections [for the number of parameters] have no appreciable effect." That is, the standard errors of the parameter estimates are asymptotic. Nonetheless, in small samples, the adjustment for degrees of freedom for the number of estimated parameters is made from the total number of observations (i.e., Tn, where T indexes time and n indexes the number of equations that are estimated). In our models, the total number of observations is 108.

Table 1. Definition of Variables

Variable	Definition
Dependent:	
QNF	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$0.55 per pound) on nonfed beef
QFD	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$1.04 per pound) on fed beef
QPK	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$0.67 per pound) on pork
QPY	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$0.40 per pound) on poultry
QNMN	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on nonmeats in the nonfed model
QGB	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$0.55 per pound) on ground beef
QTC	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967 = \$1.06 per pound) on table cut beef
QNMG	Weighted first differences of the natural logarithm of per capita constant dollar expenditures (1967) on nonmeats in the ground model
Independent:	
INCOMEN	Income in the nonfed beef model. Calculated as the difference between the first differences of the natural logarithm of per capita personal consumption expenditures and the sum of the shares weighted price variables of the nonfed model
INCOMEG	Income in the ground beef model. Calculated as the difference between the first differences of the natural logarithm of per capita personal consumption expenditures and the sum of the shares weighted price variables of the ground model
PNF	First differences of the natural logarithm of the price index of nonfed beef (the price index of hamburger is used as a proxy), 1967 = 100
PFD	First differences of the natural logarithm of the price index of fed beef, 1967 = 100. Given estimated expenditures on all beef and nonfed beef, *PFD* is calculated using the price index for all beef and veal and *PNF* (Wohlgenant, p. 172)
PPK	First differences of the natural logarithm of the price index of pork, 1967 = 100
PPY	First differences of the natural logarithm of the price index of poultry, 1967 = 100
PNMN	First differences of the natural logarithm of the price index of nonmeats in the nonfed model, 1967 = 100. Given expenditures on all meat, PNMN is calculated using the CPI and the price indices of the individual meat products (Wohlgenant, p. 172)
PGB	First differences of the natural logarithm of the price index of ground beef (the price index of hamburger is used as a proxy), 1967 = 100
PTC	First differences of the natural logarithm of the price index of table cut beef, 1967 = 100. Given estimated expenditures on all beef and ground beef, *PTC* is calculated using the price index for all beef and veal and *PGB* (Wohlgenant, p. 172)
PNMG	First differences of the natural logarithm of the price index of nonmeats in the nonfed model, 1967 = 100. Given expenditures on all meat, *PNMG* is calculated using the CPI and the price indices of the individual meat products (Wohlgenant, p. 172)

Sources: Price and income data are from USDA *Food Consumption, Prices and Expenditures*, various issues. The construction of the quantity data is described in the text and the appendix.

modities. The intercept term for poultry consumption shows a significant trend effect at the 0.05 level, while the trend effect for fed beef consumption is significant at the 0.10 level.

The lower portion of table 2 reports the regression results for the ground beef system.[6] Again, both homogeneity and symmetry are imposed, and the substitution matrix is negative semidefinite. Ground beef appears to be an inferior good; however, its estimated income coefficient is not statistically different from zero. All commodities are substitutes except for table cut beef and poultry. However, the parameter estimate is not significantly different from zero. Trend effects again are strongly significant for poultry consumption and marginally significant

[6] The R-square statistics for the ground, table cut, pork, and poultry equations are 0.53, 0.57, 0.81, and 0.48, respectively. The D-W statistics do not suggest the presence of serial correlation.

Table 2. Estimated Regression Coefficients of the Nonfed and Ground Beef Systems of Meat Demand Equations

	Independent Regressors for the Nonfed System[a]						
Dependent Variables for the Nonfed System	*PNF*	*PFD*	*PPK*	*PPY*	*PNMN*	*INCOMEN*	Intercept
QNF	−0.145	.0110	.0037	.0010	−.0012	−.0110	.00016
	(−4.06)	(2.29)	(3.25)	(1.21)	(−0.57)	(−1.94)	(0.91)
QFD		−.0221	−.0006	−.0001	.0118	.0358	−.00060
		(−2.94)	(−0.35)	(−0.06)	(2.95)	(3.40)	(−1.87)
QPK			−.0103	.0004	.0068	.0041	−.00010
			(−12.44)	(1.14)	(4.53)	(0.94)	(−0.75)
QPY				−.0020	.0007	.0029	.00012
				(−4.04)	(1.35)	(2.08)	(2.73)
QNMN					−.0181	.9682	
					(−4.02)	(75.64)	

	Independent Regressors for the Ground System[a]						
Dependent Variables for the Ground System	*PGB*	*PTC*	*PPK*	*PPY*	*PNMG*	*INCOMEG*	Intercept
QGB	−.0063	.0025	.0022	.0015	.0001	−.0012	.00005
	(−6.63)	(1.90)	(4.05)	(3.18)	(0.10)	(−0.43)	(0.60)
QTC		−.0151	.0018	−.0007	.0115	.0150	−.00033
		(−6.87)	(1.88)	(−1.11)	(5.48)	(2.44)	(−1.78)
QPK			−.0107	.0004	.0063	.0047	−.00012
			(−11.24)	(1.09)	(6.56)	(1.00)	(−0.84)
QPY				−.0020	.0008	.0028	.00013
				(−4.00)	(1.60)	(1.99)	(2.94)
QNMG					−.0187	.9787	
					(−4.81)	(86.61)	

[a] Numbers in parenthesis are the *t*-values for the parameter estimates.

for table cut beef consumption. This model shows that ground beef is a substitute for poultry, while the nonfed model indicates that the cross-price effect of nonfed beef to poultry is not significantly different from zero.

The estimated price and income elasticities for both models are presented in table 3. The elasticities for the nonfed beef system are presented in the upper portion of the table. Most of the price elasticities are less than one in absolute value. The three exceptions are the own-price elasticities of nonfed and fed beef and the cross-price elasticity of nonfed beef to fed beef. The own-price elasticity of nonfed beef is more elastic than that of fed beef. These results are similar to those of Eales and Unnevehr who used nonfed and fed beef as proxies for hamburger and table cut beef, respectively.

The elasticity estimates for the ground beef system are reported in the lower portion of table 3. The own-price elasticity of ground beef is unity. All of the other price elasticities are less than one in absolute value. Contrary to the nonfed model, the cross-price elasticity of ground beef to table cut beef is inelastic. The income elasticities for ground beef and table cut beef are both inelastic, and ground beef is an inferior good.[7]

The own-price elasticity of demand for an aggregate beef commodity can be calculated for each model by adding the quantity-share weighted sums of the own- and cross-price elasticities of the disaggregated beef components (Wold and Jureen). The aggregate beef elasticity for the nonfed model is calculated as -0.59, while that for the ground model is -0.65.

A Nonnested Test of the Alternative Specifications

While the two sets of demand elasticity estimates appear to differ from one another, we are left to decide which set is more appropriate. Davidson and MacKinnon (1983) propose the P_1-test as a nonnested test of the alternative multivariate model specifications. Two models are nonnested if neither can be obtained from the other via the imposition of parametric constraints. The goal is to test whether one model, say H_1, could have generated the data by evaluating an alternative nonnested model, say H_2, to see if the latter is consistent with the former. Because it is possible to reject both models, such tests are best characterized as tests of model specification rather than as criteria to be used for model selection (Shideed and White). Nonetheless, such tests can be used to provide evidence of model misspecification in one or both of the models (MacKinnon).

The P_1-test requires the dependent variables in each model be identical. In the present example, the pork and poultry dependent variables are the same but those of the beef equations are not. MacKinnon, White, and Davidson develop a nonnested test for model specification for univariate models which have dependent variables that are related by a monotonic, continuously differentiable function which does not depend upon any unknown parameters. They refer to this test as the P_E-test because it is an extension of Davidson and MacKinnon's (1981) P-test. The P_E-test uses predicted values of the dependent variables of the alternative model that have been transformed using the same function that relates the observed dependent variables of the two models. In our case, the transformation is a linear function from one dependent variable to the other. Our generalization of the test to multivariate models parallels Davidson and MacKinnon's (1983) extension of the univariate P-test to the multivariate P_1-test. MacKinnon, White, and Davidson note that the P_E-test does not have any theoretic optimality properties. They report, however, that the test has reasonable power in applied problems and its "theoretical deficiencies may be of small consequence to applied workers who find its simplicity appealing" (p. 56).

The P_E-test is based on an artificial linear regression. For linear models, the multivariate version of the P_E-test is implemented using the following seemingly unrelated regression (SUR):

$$(3) \qquad Y_1 - \hat{Y}_1 = X_1\Theta + H_1\alpha + e,$$

where the subscript refers to the model which is chosen as the null hypothesis (i.e., 1 for the nonfed model or 2 for the ground model), X_1 is a $T \times K$ matrix of independent variables, Θ is a $K \times n$ matrix of parameters, e is a $T \times n$

[7] The Rotterdam and almost ideal demand system (AIDS) models appear to be the two most popular choices of functional forms for estimating systems of demand equations. The nonfed and ground models were both estimated using the first-differences form of the linear approximate AIDS model to see if the differences in the elasticity estimates between the two data sets were merely a product of the choice of functional form. All of the elasticity estimates from the AIDS models were very similar to those of the Rotterdam models.

Table 3. Estimated Compensated Price and Income Elasticities for the Nonfed and Ground Beef Systems of Meat Demand Equations

Nonfed Beef System

Elasticity of the Quantity of	With Respect to the Price of					With Respect to
	Nonfed Beef	Fed Beef	Pork	Poultry	Nonmeats	Income
Nonfed beef	−2.543	1.926	.650	.147	−.210	−1.933
Fed beef	.575	−1.155	−.033	−.004	.617	1.869
Pork	.271	−.046	−.775	.030	.497	.300
Poultry	.151	−.011	.063	−.303	.106	.444

Ground Beef System

Elasticity of the Quantity of	With Respect to the Price of					With Respect to
	Ground Beef	Table Cuts	Pork	Poultry	Nonmeats	Income
Ground beef	−1.015	.408	.348	.241	.016	−.197
Table cuts	.136	−.811	.094	−.040	.619	.805
Pork	.158	.128	−.779	.030	.461	.343
Poultry	.225	−.112	.062	−.296	.121	.417

matrix of error terms, and Y_1 is a $T \times n$ matrix of observed values of the dependent variables. A $T \times n$ matrix of the predicted values of the dependent variables, $\hat{Y}_1$, is calculated by

$$\hat{Y}_1 = X_1\hat{\beta}_1, \tag{4}$$

where $\hat{\beta}_1$ is a $K \times n$ matrix of the estimated parameters of the nonfed model. Thus, the matrix of dependent variables of equation (3) consists simply of the residuals of the model representing the null hypothesis.

The matrix H_1' is an $n \times T$ matrix defined as

$$H_1' = \hat{\Sigma}_1\hat{\Sigma}_2^{*-1}[Y_2^* - \hat{Y}_1]', \tag{5}$$

where Y_2^* are the predicted values of the alternative hypothesis which have been transformed by the function that relates Y_1 to Y_2, $\hat{\Sigma}_1$ is the estimated covariance matrix of the residuals of the model assumed to be the null hypothesis, and $\hat{\Sigma}_2^*$ is the estimated covariance matrix of the residuals obtained from the differences between Y_2 and Y_2^*. Equation (3) is then estimated by SUR with the covariance matrix $\hat{\Sigma}_1$ serving as an estimate of the contemporaneous covariance matrix for e (Chalfant). The diagonal matrix α is of dimension $n \times n$. Upon setting each of the diagonal elements of α to be equal, the ratio of the estimate of the single remaining α to its standard error converges in distribution to $N(0, 1)$. Consequently, the multivariate P_E-test is simply a t-test to determine if α is significantly different from zero. If it is, then the hypothesis that H_1 is correctly specified is rejected because the predictions of the alternative hypothesis add to the explanatory power of the system.[8]

In the present application, the dependent variables of the nonfed and ground models are not identical. Recall that the pork and poultry dependent variables are the same for both models, but those for nonfed and fed beef differ from the values for ground and table cut beef. However, the sum of the nonfed and fed beef dependent variables is equal to the sum of the ground and table cut beef dependent variables. The exploitation of these identities allows for predicted values of the dependent variables of the ground model to be used as predictions of the values of the dependent variables of the nonfed model (and vice versa). Thus, the multivariate P_E-test can be used as a test of model specification.

To show how the two models can be converted to predictions of the same dependent

[8] Note that the P_E-test involves regressing the residuals of the maintained model specification on the regressors of the original model and one new variable in each of the equations. This new variable is the difference between the predicted values of the alternative and maintained specifications. For models which are nonlinear in parameters, the original regressors must be replaced with the derivatives of the maintained model with respect to the parameters.

variables, let s_N be a $T \times T$ diagonal matrix whose elements represent the proportion that nonfed beef consumption is of total beef consumption, such that

$$(6) \qquad s_F = I - s_N,$$

where I is a $T \times T$ identity matrix. Thus, s_F is a $T \times T$ diagonal matrix—the diagonal elements of which represent the proportion that fed beef consumption is of total beef consumption. Let Z be a $T \times 1$ vector of total beef consumption. Then, by definition, N is a $T \times 1$ vector of nonfed beef consumption that is calculated by

$$(7) \qquad N = s_N Z,$$

Similarly,

$$(8) \qquad F = s_F Z,$$

where F represents a $T \times 1$ vector of fed beef consumption.

Furthermore, let s_G and s_c represent $T \times T$ diagonal matrices whose diagonal elements represent the proportions of ground beef and table cut beef consumption relative to total beef consumption, respectively. The consumption of ground beef and table cut beef can then be represented by the following $T \times 1$ vectors

$$(9) \qquad G = s_G Z,$$

$$(10) \qquad C = s_C Z.$$

Rewriting equations (7) and (9) in first differences of logarithms yields

$$(11) \qquad \Delta \ln N = \Delta \ln s_N + \Delta \ln Z, \text{ and}$$

$$(12) \qquad \Delta \ln G = \Delta \ln s_G + \Delta \ln Z.$$

Let w_N be a $T \times T$ diagonal matrix of the expenditure share weights of nonfed beef, and w_G be a $T \times T$ diagonal matrix of the expenditure share weights of ground beef. (Expenditure shares are average values between adjoining time periods as in equation (1), however, overbars have been omitted for notational convenience.) By premultiplying each of the arguments in equations (11) and (12) by w_N and w_G, respectively, the left-hand side of those two equations can be put in a form that is consistent with the dependent variable formulation of the Rotterdam model. That is,

$$(13) \qquad w_N \Delta \ln N = w_N \Delta \ln s_N + w_N \Delta \ln Z, \text{ and}$$

$$(14) \qquad w_G \Delta \ln G = w_G \Delta \ln s_G + w_G \Delta \ln Z.$$

Solving equation (12) for $\Delta \ln Z$ and substituting into equation (13) yields

$$(15a) \qquad w_N \Delta \ln N = w_N \Delta \ln s_N + w_N (\Delta \ln G - \Delta \ln s_G),$$

or upon rearranging terms,

$$(15b) \qquad w_N \Delta \ln N = w_N \Delta \ln G - w_N \Delta \ln s_G + w_N \Delta \ln s_N.$$

Noting that $w_G^{-1} w_G$ is a $T \times T$ identity matrix, we can premultiply $\Delta \ln G$ in equation (15b) by this matrix to yield

$$(15c) \qquad w_N \Delta \ln N = w_N (w_G^{-1} w_G) \Delta \ln G - w_N \Delta \ln s_G + w_N \Delta \ln s_N,$$

or, after some rearrangement of terms,

$$(15d) \qquad w_N \Delta \ln N = w_N w_G^{-1} (w_G \Delta \ln G) + w_N (\Delta \ln s_n - \Delta \ln s_G).$$

The left-hand side of equation (15d) is the dependent variable of the nonfed beef equation in the nonfed (Rotterdam) model and the term $(w_G \Delta \ln G)$ is the dependent variable of the ground beef equation in the ground model. Thus, equation (15d) shows the relationship between the nonfed and ground beef dependent variables in terms of a monotonic, continuously differentiable function that does not depend upon any unknown parameters.

Similarly, if we let w_F be a $T \times T$ diagonal matrix of the expenditure share weights of fed beef and w_c be a $T \times T$ diagonal matrix of the expenditure share weights of table cut beef, then the relationship between the dependent variables of the fed beef equation in the nonfed model and the table cut beef equation in the ground model is provided by

$$(16) \qquad w_F \Delta \ln F = w_F w_C^{-1} (w_C \Delta \ln C) + w_F (\Delta \ln s_F - \Delta \ln s_C).$$

For the moment, consider the nonfed model as the null hypothesis for the multivariate P_E-test, and let Y_1 represent the observed dependent variables of the nonfed model, such that

$$(17) \qquad Y_1 = [w_N \Delta \ln N \mid w_F \Delta \ln F \mid w_K \Delta \ln K \mid w_P \Delta \ln P],$$

where w_K and w_P are $T \times T$ diagonal matrices whose diagonal elements are expenditure share weights of pork and poultry, respectively, K is a $T \times 1$ vector of pork consumption, and P is $T \times 1$ vector of poultry consumption. Let $\hat{Y}_1$ be

the predicted values of Y_1 as calculated by equation (4) so that the dependent variables of equation (3) are simply the residuals of the nonfed model. To perform the multivariate P_E-test, the final requirement is to obtain predicted values of Y_1 that are generated by the alternative model (i.e., the ground model). We cannot simply use the predicted values of the ground model as generated by

$$(18) \qquad \hat{Y}_2 = X_2\hat{\beta}_2$$

because the observed dependent variables of the ground model are

$$(19) \qquad Y_2 = [w_G\Delta\ln G \mid w_C\Delta\ln C \mid w_K\Delta\ln K \mid w_P\Delta\ln P].$$

As previously mentioned, the first two columns of Y_2 (i.e., the ground model) differ from those of Y_1 (i.e., the nonfed model).

It is possible, however, to obtain predicted values from the alternative (ground) model for the dependent variables of the nonfed model via the use of equations (15d) and (16). The procedure is to use predicted values of $w_G\Delta\ln G$ obtained from the ground beef model [i.e., equation (18)] in equation (15d) to obtain predicted values of $w_N\Delta\ln N$. Predicted values obtained in this manner are designated with a ~. Similarly, predicted values of fed beef can be generated by the ground model by using predicted values of $w_c\Delta\ln C$ [which are also obtained from equation (18)] in equation (16). Recall that the dependent variables of the pork and poultry equations are identical between the two models. Thus, for these two variables, predicted values as calculated by equation (18) (i.e., the ground model) can be directly compared to those from the nonfed model. These predicted values are designated with a ^. Therefore, Y_2^* is defined in equation (5) as

$$(20) \qquad Y_2^* = [w_N\tilde{\Delta}\ln N \mid w_F\tilde{\Delta}\ln F \mid w_K\hat{\Delta}\ln K \mid w_P\hat{\Delta}\ln P].$$

With the nonfed model specification as the maintained hypothesis, the estimation of equation (3) results in an estimate of α of 0.08 with a t-value of 4.80. Therefore, we reject the null hypothesis that the nonfed model is correctly specified.

Judge et al. note that the results of many nonnested model specification tests are dependent upon the choice of the reference hypothesis. Thus, conclusions regarding model misspecification may not be symmetric with respect to the model chosen as the maintained hypothesis. Consequently, it is necessary to consider the multivariate P_E-test with the null hypothesis that the ground model is correctly specified. This reverses the roles of the two models. In this case, the value of α is estimated to be 0.37. The t-value, however, is only 0.84, which indicates that the null hypothesis that the ground model is correctly specified cannot be rejected.[9]

Conclusions

Nonfed beef production historically has been used as a proxy for ground beef consumption in demand analysis. An alternative measure for ground beef production is derived using a methodology proposed by the WLMIP. The two sets of data are used to estimate demand elasticities using the absolute price version of the Rotterdam model. The price elasticity estimates for hamburger and table cuts of beef are substantially influenced by the choice of data.

A multivariate version of MacKinnon, White, and Davidson's P_E-test is developed and used as a nonnested test for model specification. The test is appropriate in cases where the dependent variables of two models are not the same but are related by a monotonic, continuously differentiable function that does not depend upon any unknown parameters. This often occurs when alternative sets of data are available which describe a single data-generating process or when

[9] A reviewer expressed an opinion that the P_E-test developed here is inappropriate because the relationship between the Rotterdam model dependent variables in equations (15d) and (16) depend upon stochastic terms (i.e., that the quantity share weights, s_N and s_G, are stochastic). The reviewer notes that, to the extent that this is true, the variance of the nesting parameter will be too small. Thus, the test is biased towards rejection. However, one can think of the quantity share weights as *ex post* observable values for any given time period. Therefore, the nonfed and ground data differ only because of the researcher's choice of a disaggregation method. Thus, as Theil (chap. 3) and Gallant (pp. 158–71) note, regression analyses may proceed on the basis that the results are conditional on these particular realizations of the data. Viewed in this context, the P_E-test developed here is a valid procedure because the transformations described in equations (15d) and (16) do not depend on any unknown parameters. Nonetheless, the asymptotic behavior of the nesting parameter, α, was examined by bootstrapping the residuals obtained from the P_E-test (Efron). One thousand iterations were performed and the null hypothesis that α is distributed normally could not be rejected (P-value $< .01$). If the estimated variance of α was too small, then the null hypothesis that the nonfed model is correctly specified would be falsely rejected. However, the bootstrap results indicate that the null hypothesis of $\alpha = 0$ is still strongly rejected for the case where the nonfed model is the null hypothesis. Thus, at least for these data, the P_E-test asymptotically yields valid conclusions.

selecting between functional forms that employ different transformations of the dependent variables. The multivariate P_E-test favors the ground beef model over the nonfed beef model. Since the only difference between the two models is the construction of the beef data, we conclude that the ground beef data are superior to the nonfed beef data. Nonfed and fed beef production are at best proxies for the consumption of hamburger and table cut beef. The WLMIP procedure for estimating the production of ground beef is intuitively appealing in that consideration is given to the composition of the actual production of ground beef. In addition, the ground beef data (i.e., the series reported by the WLMIP which begins in 1970) are more readily available to researchers than are the nonfed data.

However, as previously noted, the ground beef data are constructed with the unrealistic assumption that fixed proportions of beef carcasses are processed into ground beef. This data might be improved by allowing these proportions to be influenced by economic factors, thus making the weights attached to each category of beef animal time variant. Extending the ground beef data in this manner may yield further improvements in estimated demand elasticities for ground and table cut beef.

[Received August 1989; final revision received January 1991.]

References

Arzac, Enrique R., and Maurice Wilkinson. "A Quarterly Econometric Model of U.S. Livestock and Feed Grain Markets and Some of Its Policy Implications." *Amer. J. Agr. Econ.* 61(1979):297–308.

Barten, Anton P. "Maximum Likelihood Estimation of a Complete System of Demand Equations." *Eur. Econ. Rev.* 1(1969):7–73.

——. "The System of Demand Functions Approach: A Review." *Econometrica* 45(1977):23–51.

Brester, Gary W., and John M. Marsh. "A Statistical Model of the Primary and Derived Market Levels in the U.S. Beef Industry." *West. J. Agr. Econ.* 8(1983):34–49.

Chalfant, James A. "A Globally Flexible, Almost Ideal Demand System." *J. Bus. and Econ. Statist.* 5(1987):233–42.

Chalfant, James A., and Julian M. Alston. "Accounting for Changes in Taste." *J. Polit. Econ.* 96(1988):391–410.

Christensen, Laurits R., and Marilyn E. Manser. "Estimating U.S. Consumer Preferences for Meats with a Flexible Utility Function." *J. Econometrics* 5(1977):37–53.

Davidson, Russell, and James G. MacKinnon. "Several Tests for Model Specification in the Presence of Alternative Hypotheses." *Econometrica* 49(1981):781–93.

——. "Testing the Specification of Multivariate Models in the Presence of Alternative Hypotheses." *J. Econometrics* 23(1983):301–13.

Efron, B. "Bootstrap Methods: Another Look at the Jackknife." *Ann. Statist.* 7(1979):1–26.

Eales, James S., and Laurian J. Unnevehr. "Demand for Beef and Chicken Products: Separability and Structural Change." *Amer. J. Agr. Econ.* 70(1988):521–32.

Freebairn, J. W., and Gordon C. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." *Amer. J. Agr. Econ.* 57(1975):676–88.

Gallant, A. Ronald. *Nonlinear Statistical Models*. New York: John Wiley & Sons, 1987.

Judge, George C., William E. Griffiths, R. Carter Hill, Helmut Lutkepohl, and Tsoung-Chao Lee. *The Theory and Practice of Econometrics*, 2nd ed. New York: John Wiley & Sons, 1985.

MacKinnon, James G. "Model Specification Tests Against Nonnested Alternatives." *Econometric Rev.* 2(1983):85–110.

MacKinnon, James G., Halbert White, and Russell Davidson. "Tests for Model Specification in the Presence of Alternative Hypotheses: Some Further Results." *J. Econometrics* 21(1983):53–70.

Mountain, D. C. "The Rotterdam Model: An Approximation in Variable Space." *Econometrica* 56(1988):477–84.

Nelson, Kenneth E., and Lawrence A. Duewer. "ERS's Measures of Red Meat Consumption." *The Economics of Meat Demand*, ed. Rueben C. Buse, pp. 57–73. Madison: University of Wisconsin, 1989.

SAS/ETS User's Guide, Version 5 Edition. Cary NC: SAS Institute, 1984.

Shideed, Kamil H., and Fred C. White. "Alternative Forms of Price Expectations in Supply Analysis for U.S. Corn and Soybean Acreages." *West. J. Agr. Econ.* 14(1989):281–92.

Theil, Henri. *Principles of Econometrics*. New York: John Wiley & Sons, 1971.

——. *The System-Wide Approach to Microeconomics*. Chicago: University of Chicago Press, 1980.

U.S. Department of Agriculture. *Food Consumption, Prices, and Expenditures*. Washington DC, biennial, selected issues.

——. "Livestock and Poultry Situation and Outlook Report." Washington DC, Jan., July 1990.

Western Livestock Marketing Information Project. Table 6.110 and personal communication. Denver CO.

Wohlgenant, Michael K. "Effects of the Changing Composition of Beef Consumption on the Elasticities for Beef and Poultry." *The Economics of Meat Demand*, ed. Rueben C. Buse. pp. 170–86. Madison: University of Wisconsin, 1989.

Wold, Herman, and Lars Jureen. *Demand Analysis*. New York: John Wiley & Sons, 1953.

Appendix

Per Capita Beef Consumption

Year	All Beef and Veal[a]	Ground Beef[b]	Table Cut Beef[c]	Fed Beef[d]	Nonfed Beef[e]
1962	70.7	27.9	42.8	36.7	34.0
1963	74.3	29.3	45.0	40.2	34.1
1964	79.1	31.2	47.9	43.5	35.6
1965	79.0	32.3	46.7	43.2	35.8
1966	82.0	33.0	49.0	47.3	34.7
1967	83.1	32.5	50.6	50.7	32.4
1968	85.1	33.1	52.0	54.1	31.0
1969	85.3	33.2	52.1	56.5	28.8
1970	86.8	32.8	54.0	59.7	27.1
1971	85.9	32.6	53.3	59.6	26.3
1972	87.4	32.7	54.7	63.1	24.3
1973	82.0	31.6	50.4	59.4	22.6
1974	87.3	34.6	52.7	55.6	31.7
1975	91.4	40.7	50.7	46.8	44.6
1976	97.4	41.3	56.1	55.9	41.5
1977	94.5	38.5	56.0	56.1	38.4
1978	89.6	35.9	53.7	59.3	30.3
1979	79.7	30.7	49.0	55.3	24.4
1980	77.9	30.8	47.1	52.2	25.7
1981	78.7	30.9	47.8	52.1	26.6
1982	78.4	31.7	46.7	52.2	26.2
1983	79.8	31.9	47.9	53.8	26.0
1984	79.9	32.3	47.6	53.3	26.6
1985	80.6	31.5	49.1	55.3	25.3
1986	80.3	32.7	47.6	54.0	26.3
1987	77.0	31.0	46.0	52.7	24.3
1988	73.7	30.2	43.5	53.4	20.3
1989	70.1	28.9	41.2	45.2	24.7

Note: All beef and veal consumption in the table are on a retail weight basis, in pounds.

[a] Sources: 1962–88—USDA *Livestock and Poultry Outlook and Situation*, January 1990; 1989—USDA *Livestock and Poultry Outlook and Situation*, July 1990.

[b] Calculated by following WLMIP procedures. The WLMIP reports in their table 6.110 estimates of ground beef production that are generally smaller than those reported above. This is because their calculations are based on commercial livestock slaughter. The values in this column are based on total livestock slaughter which includes both commercial and farm slaughter. It is appropriate to use total slaughter because the values in column 2 are based on the sum of commercial and farm slaughter (Nelson and Duewer). The WLMIP procedures are outlined below and can be applied to either quarterly or annual data.

Data Available from USDA Sources:

*FCM*13	Fed cattle marketed in 13 states (1,000 head)
PSF	Percent of steers on feed
TSS	Total steer slaughter (1,000 head)
THS	Total heifer slaughter (1,000 head)
TBP	Total beef production, carcass-weight (mil. lbs.)
CBP	Cow beef production, carcass-weight (mil. lbs.)
BBP	Bull beef production, carcass-weight (mil. lbs.)
BIMP	Beef imports, retail-weight (mil. lbs.)
POP	Population, 1 July resident (millions)

WLMIP Procedures for Calculating Fed and Nonfed Beef Production:

Fed steer slaughter (FSS) = ($FCM13*1.13$)$*PSF$.
Fed heifer slaughter (FHS) = ($FCM13*1.13$)$-FSS$.
[Note: For some years, fed cattle marketings are based on data from 23 states. In these cases, *FCM*13 is multiplied by 1.03 rather than 1.13.]
Nonfed steer slaughter (NSS) = $TSS-FSS$.
Nonfed heifer slaughter (NHS) = $THS-FHS$.
Total steer and heifer production ($TSHP$) = $TBP-CBP-BBP$.

$$\text{Fed steer weight } (FSW) = \frac{[TSHP + (NSS*80) + (FHS*90) + (NHS*170)]}{[FSS + FHS + NSS + NHS]}$$

Fed heifer weight (FHW) = $FSW-90$.
Nonfed steer weight (NSW) = $FSW-80$.
Nonfed heifer weight (NHW) = $FSW-170$.

Fed steer production (FSP) = $FSS*FSW$.
Fed heifer production (FHP) = $FHS*FHW$.
Total fed production (TFP) = $FSP + FHP$.
Total nonfed production (TNP) = $TSHP-TFP$.

WLMIP Procedure for Calculating Ground Beef Production (retail weight):

Ground beef production from cows ($GBPC$) = CBP*0.90*0.73.
Ground beef production from bulls ($GBPB$) = BBP*1.0*0.73.
Ground beef production from fed beef ($GBPF$) = TFP*0.25*0.66.
Ground beef production from nonfed beef ($GBPN$) = TNP*0.45*0.70.
Ground beef production from imports ($GBPI$) = $BIMP$*0.80.
Total ground beef production ($TGBP$) = $GBPC + GBPB + GBPF + GBPN + GBPI$.
Per capita ground beef production ($PCGBP$) = $TGBP/POP$.

[c] Per capita table cut beef = column 2 − column3

[d] Per capita fed beef = $TFP*CONV/POP$.
$CONV$ = Carcass-to-retail weight conversion factor (Nelson and Duewer); 1962–85; $CONV$ = 0.74. 1986–89; $CONV$ = 0.73.

[e] Per capita nonfed beef = column 2 − column 5.

Advertising, Information, and Product Quality: The Case of Butter

Hui-Shung Chang and Henry W. Kinnucan

This study examines the roles of cholesterol information and advertising in explaining consumption trends for fats and oils, focusing on butter. Results suggest increased consumer awareness of the health effects of blood cholesterol has contributed to the secular decline in butter consumption in Canada. Although consumers' responses to negative information appear to outweigh their responses to positive information, the industry advertising campaign launched in 1978 by the Dairy Bureau of Canada has had a positive effect on butter demand.

Key words: advertising, attribution theory, butter, cholesterol, health information.

Advertising of food products by farm groups has increased significantly in recent years as a result of enabling legislation authorizing nationwide mandatory check-off programs for such commodities as beef, pork, and dairy products. Yet, at the same time consumers are receiving more information about the favorable attributes of these commodities, health authorities and the media continue to warn consumers about the health risks of consuming foods high in saturated fats and cholesterol. The potentially conflicting information provided by industry and the government (among others) raises questions about the ability of expensive advertising campaigns (amounting to $254 million for dairy and meat in 1986 alone, according to Armbruster and Frank, p. 4) to improve perceptions of product quality, and thereby increase demand.

This study uses butter in Canada to address whether industry-provided information can be effective in a marketplace regularly exposed to unfavorable information. Butter is generally regarded as high in cholesterol, calories, and saturated fats and therefore is implicated in studies linking heart disease to diet; butter consumption has declined in part because a close substitute, margarine, is less expensive and is perceived as lower in calories and cholesterol (Tandemar Research Inc.). Butter has a relatively long history (in Canada) of farm-funded advertising.

Previous research has addressed the roles of health concerns (e.g., Brown and Schrader, Putler, Chalfant and Alston) and advertising (e.g., Goddard and Amuah, Chang and Kinnucan, Kinnucan 1986) in explaining the consumption trends of individual food items by examining each factor in isolation. This research adds to the existing literature by considering health and advertising effects together in a single model of consumer response to information.

The purpose of this study is to determine the relative significance of economic factors (prices and income) and noneconomic factors (advertising and health concerns) in affecting butter demand in Canada. A major hypothesis is whether consumers respond disproportionately to unfavorable information, as suggested by attribution and related theories (Mizerski, Weinberger and Dillon). A brief review of the relevant literature precedes discussion of the model and hypothesis testing.

Source and Quality of Information

In this paper, consumers' tastes and preferences, and hence their perceptions of product quality, are assumed to be subject to change through advertising and health information. Although information can be defined in several ways

---

Hui-Shung Chang and Henry W. Kinnucan are, respectively, a visiting assistant professor and an associate professor, Department of Agricultural Economics and Rural Sociology, Auburn University.

Scientific Journal Paper No. 1-902664P of the Alabama Agricultural Experiment Station.

The authors express appreciation to Deborah Brown for providing data used for the cholesterol index; to Ellen Goddard, Andrew MacDonald, and Archie MacDonald for providing data and background information on fats and oils advertising; and to colleagues and two *Journal* referees for helpful comments on earlier versions of this manuscript. Responsibility for final content, of course, remains with the authors.

(Pope), in this analysis it is defined as anything that alters beliefs (Hirschleifer).

Information can be classified by type, e.g., biased versus unbiased, accurate versus inaccurate, or favorable versus unfavorable. It is argued that unfavorable product information may weigh more in decision making than similar amounts of favorable information (Weinberger and Dillon). Unfavorable information (negative cues) may have a greater impact because it is less common in an individual's social environment than the positive cues of favorable information (Kanouse and Hanson). Therefore, negative cues counter expectations, carry an element of surprise, and prompt greater attention.

Another explanation, called attribution theory, states that the cause of information is important (Mizerski). That is, individuals process information according to its perceived cause and consider information provided by the factual performance of the entity in question more reliable than information provided by other factors (e.g., vested interest, as might be the case with advertising). Consequently, unfavorable information has more dispositional value to an object, is discounted less, and therefore disproportionately influences impressions, beliefs, and attitude (Feldman).

A related hypothesis suggests that the source and type of information have differing impacts on consumers. In general, personal and neutral information are more influential than nonpersonal and market-oriented information (Engel and Blackwell, pp. 333–34). Information from personal interaction is more influential because of the potential for feedback between sources and receptors. Information of a neutral nature, such as that provided by the news media or other objective sources, is more effective because it is considered more credible than advertising and other market-oriented sources. In short, information resulting from personal interaction is considered more effective than information obtained from the news media, which, in turn, is considered more effective than information contained in advertisements.

The Model

Consumers' preferences are assumed to depend on what and how much they know about the product. Swartz and Strand suggest that consumers' perceptions of the quality (Z) of a good (X) affect the satisfaction or utility experienced in consuming the good. Further, a consumer's perceptions of product quality will depend on the information (N) that a consumer has about product attributes. Thus, the consumer's utility function can be expressed as

$$U = U(X(Z(N))). \tag{1}$$

Recognizing that not all information has the same impact on the consumer, equation (1) can be re-expressed as

$$U = U(X(Z(N_1, N_2(A)))), \tag{2}$$

where N_1 represents unfavorable product information provided by neutral sources and N_2 represents favorable product information provided by nonneutral sources, e.g., advertising (A).[1] Here, N_1 is hypothesized to have a negative impact and to be more effective than N_2 in influencing consumers' quality perceptions.

Assuming weakly separable utility and multiple-stage maximization (Pollak), the utility function can be partitioned into separate subsets or branches, such as food or, at a more disaggregated level, fats and oils. Consumers decide first on their total consumption of food, then on the budget allocation among food groups, and finally on the allocation among individual commodities within a specific food grouping.

Empirical Specification

The empirical implication of the multistage utility maximization hypothesis is that the demand functions for individual commodities within a branch can be specified as a function of the prices of the goods in that branch and total expenditures of goods on the branch (Pollak, p. 426). Such demand functions are called conditional to highlight the fact that the effect of total income and prices of goods outside the branch enter the group demand functions through the budget allocation for goods in the branch (Phlips, p. 73). An advantage of the conditional demand function formulation in empirical work is that, once the budget allocation to goods within the branch is known, prices of goods outside the branch can be ignored.

Following Goddard and Amuah, we assume the fats and oils category represents a (weakly) separable food grouping, and conditional demand equations, in semilog form, are specified for butter, margarine, shortening, and salad oils.

[1] Some might question whether food advertising as commonly observed on television provides any useful information. Yet Nelson, among others, argues cogently that all advertising conveys information in that the mere presence of advertisements reminds consumers of the product's existence and may signal product quality.

A semilogarithmic form was chosen because it is compatible with utility maximization (Hanemann) and permits modeling diminishing returns to advertising (Kinnucan 1985) and diminishing marginal effectiveness of health information (Brown and Schrader, p. 549).[2]

The estimated equations are

$$(3)\quad Q_{i,t} = a_i + \Sigma_j \alpha_j \ln P_{j,t} + \beta_i \ln (TEXP_t/P_t^*) + n_i \ln INFO_t + \Sigma_k c_k D_k + \xi_{i,t},$$

where t represents quarterly observations and $t = 1, \ldots, 54$ (1973.2 through 1986.3); Q_i is per capita consumption of good i, ($i = 1, \ldots, 4$); P_j is the real price of good j; $TEXP$ is consumer's total group expenditure on fats and oils deflated by the Stone price index, $P_t^* = \Sigma_j w_{j,t} \ln p_{j,t}$ (Deaton and Muellbauer, p. 62), where w_j is the consumer's budget share of good j in the fats and oils group and p_j is nominal price of good j in period t; $INFO$ is consumer information on cholesterol received from neutral sources (to be discussed later); D_k's are seasonal dummy variables (the fourth quarter being the omitted category); and ξ_i's are random error terms. The deflator for prices and advertising expenditures is the consumer price index for all items (1981 = 100).

It has been long argued that advertising changes demand elasticities (Albion and Farris, Quilkey). For example, Quilkey argues advertising that seeks to impart knowledge about product attributes and to improve consumers' perceptions about the uniqueness of the product will narrow the range of potential substitutes and tend to make demand less elastic.

To test these arguments, own-price coefficients are specified as

$$(4)\quad \alpha_i = c_i + \Sigma_j b_{i,j} \ln AD_{i,j},$$

where AD_j is the brand and generic advertising for good j; $AD_{i,j}$ represents own-advertising for good i when $i = j$ and competitive advertising for good i when $i \neq j$.[3] Butter advertising is specified linearly rather than in logarithms because of periods of zero expenditure.

As Goddard and Amuah, and Cox suggest, in the estimation both prices and advertising are assumed to be exogenous. The assumption of exogeneity is justified in the case of butter in that funds available for advertising are appropriated through an industry check-off mechanism that is contemporaneously independent of market conditions and prices are set by the government. The exogeneity assumption may be less tenable for the remaining products but is valid for price if the commodity grouping is considered sufficiently disaggregated.[4]

Measurement of Goodwill

It is well accepted that the effects of advertising linger beyond the period of initial exposure, and each new expenditure builds on the residual contribution of past outlays (e.g., Clarke, Simon and Arndt, Jastram). The carryover phenomenon can be explained by the effects of time on the retention and salience of differing types of information (Rethans, Swasy, and Marks; Krugman). Because the buildup of a favorable product image through advertising represents an intangible asset, advertising has been related to the accounting concept of goodwill (Nerlove and Waugh, Kinnucan and Forker).

Developing an empirical measure of goodwill involves specifying a lag distribution. Two issues are relevant: the length of the carryover period and the decay rate. Based on previous research related to fats and oils (e.g., Cox, Chang and Kinnucan) and Clarke's survey of the econometric literature, in which he concluded that mature, low-cost, frequently purchased items tend to exhibit an advertising lag structure ranging from three to nine months, this study posited a carryover period of nine months (three calendar quarters) for all four products.

Owing to the complexity of consumer response to advertising, specifying an appropriate decay rate is more difficult. Contrasting the underlying mechanisms of buildup and decay, Lilien and Kotler argue that, whereas buildup involves the persuasive effect of repeated exposures, the

[2] Originally an almost ideal demand system (AIDS) was specified. However, preliminary analysis with this system provided unsatisfactory results, e.g., positive own-price elasticities for a number of the commodities. Using the same data set (1973–86), Cox obtained similar results using the Rotterdam model. Because the purpose of the study is to estimate responses to information and not to test demand theory per se, the systems approach was abandoned in favor of the semilog model.

[3] Shifts in the intercept are not considered here due to severe collinearity among the advertising variables and their cross products with prices. However, the elasticities obtained from the cross products of price and advertising (to be discussed later) were found to approximate the elasticities from a model that permitted both intercept and slope shifts (Chang and Kinnucan).

[4] In a recent study of price exogeneity in demand estimation, Bronsard and Salvas-Bronsard state "the assumption of the exogeneity of prices is not a very dramatic one . . ." (p. 235) and conclude "at a very aggregated level, one must specify both demands equations and prices equations while at a less aggregated level prices may be considered as determined outside the demand system" (p. 244). Also see footnote 8.

decay phenomenon is governed by consumers' use experience with the brand or product. In addition to product use experience, copy theme, color, and competitive advertising all shape the rate at which advertising is forgotten (Ray, Sawyer, and Strong). Moreover, as emphasized by Ray, Sawyer, and Strong, it does not necessarily follow that when advertising is withdrawn decay occurs. Possibly due to tedium arousal or the noxious effects of repeated exposure, a number of studies have observed mild or even nonexistent decay effects when advertising is reduced or withdrawn (Ray, Sawyer, and Strong, p. 16).

Based on the foregoing considerations and the fact that the goodwill specification is a stock (not flow) variable, the value of which is unlikely to depreciate materially so long as advertising remains in force, the goodwill concept was implemented with the equation:

$$AD_{i,t} = \Sigma_l \psi_{i,t-l} ADEXP_{i,t-l}, \tag{5}$$

where $AD_{i,t}$ is the level of goodwill for commodity i in period t [the empirical measure of "advertising" used in equation (4)]; $ADEXP_{i,t-l}$ is total media advertising expenditures (brand and generic) for commodity i in period $t - l$; $l = 0, 1, 2, 3$ denoting the three-period carryover; and $\psi_{i,t-l}$ is a weighting factor computed as the ratio of own-advertising to total advertising (e.g., for period $l = 0$ $\psi_{i,t} = ADEXP_{i,t}/\Sigma_{j=1}^{4} ADEXP_{j,t}$) to indicate the effect of competitors' advertising on advertising for the good in question. Specifically, by placing greater weight on own-advertising in periods of relatively low levels of competing messages and less weight otherwise, the $\psi_{i,t-l}$ term reflects the fact that the ability to generate goodwill through advertising depends in part on the level of competitors' advertising.[5]

The Cholesterol Information Index

Brown and Schrader constructed a measure of cholesterol information that represents the state of scientific knowledge on the health effects of cholesterol. The index, therefore, serves as a proxy for increasing consumer awareness of cholesterol.

In constructing a cholesterol index relevant for Canada, the data base of Brown and Schrader was extended to include all medical articles published in Canada between 1966 and 1987. Following Brown and Schrader, the relevant articles were divided into those supporting the linkage between blood cholesterol levels and heart disease (negative information) and those attacking the linkage (positive information).

The impact of the scientific information on consumers' perceptions can be measured in several ways. Brown and Schrader used a "net publicity" measure in which the number of positive information articles published in each quarter was subtracted from the number of negative information articles and a running total was computed to reflect the presumed cumulative impact of the information over time. Other measures can be constructed treating the negative and positive information series as basic data. One measure is "total publicity," in which the two series are simply added together under the assumption that positive information only heightens the awareness of negative information already received and therefore is treated as negative information (Smith, van Ravenswaay, and Thompson).

In this paper, an "effective negative publicity" measure [the $INFO_t$ variable in equation (3)] is developed that is a hybrid of the above approaches. First, the negative information datum (NEG_τ) for each quarter is multiplied by a weighting factor (K_τ) computed as the ratio of negative information to the sum of negative and positive information in the respective quarter. The effective negative publicity variable is then computed as a running total using the formula

$$INFO_t = \Sigma_{\tau=1}^{t} K_\tau NEG_\tau. \tag{6}$$

Consistent with the construction of the goodwill variable, the weighting step acknowledges the potential role of the level of competing (or conflicting) information in the formation of consumers' health concerns about cholesterol.

Data

The data assembled included information on total consumption and price indices at the retail level and advertising expenditures of butter and related products (margarine, salad oils, and shortening). Prices and quantities which com-

---

[5] An exponentially distributed lag with weights declining as one goes back in time is commonly asserted as the appropriate empirical specification of the advertising variable. Yet, consistent with Nerlove and Waugh (p. 828), we found no evidence of advertising decay. The lack of decay is consistent with the arguments set forth by Ray, Sawyer, and Strong and may reflect aggregation problems associated with using expenditures as a measure of the quantity and quality of advertising messages (Kinnucan 1985, pp. 112–13).

prise both retail and commercial uses are government statistics published by Statistics Canada.[6] The advertising data were obtained from two sources. For butter, the data represent the actual (not budgeted) quarterly expenditures of Dairy Bureau of Canada generic advertising plus branded outlays that occurred as a result of special programs in which butter producers could obtain matching funds from the DBC for approved branded advertising campaigns. For the other commodities, the proprietary nature of advertising precluded going directly to the source; therefore, tracking data obtained from the Elliot Research and Media Measurement Institute, Toronto, were used.[7]

Estimation Results

Preliminary tests showed no autocorrelation or heteroscedasticity in any of the equations. The demand equations were estimated as a system using seemingly unrelated regressions under the assumption error terms are correlated across equations but not over time.[8] All elasticity estimates are evaluated at mean data points. The 5% level is used in discussing statistical significance based on *t*-tests.

Expenditure and Price Effects

Estimates of the expenditure coefficients are all positive and significant (table 1). The group expenditure elasticities for butter, margarine, shortening, and salad oils are 0.71, 1.12, 0.89, and 1.43, respectively (table 2). The estimated own-price coefficients are all negative. Except for margarine, they are significant. Estimated own-price elasticities are −0.74 for butter, −0.09 for margarine, −0.29 for shortening oils, and −0.10 for salad oils (table 2). The results indicate fat and oil products adhere to the law of demand and butter exhibits the greatest price sensitivity in the grouping.

The estimated cross-price elasticity of butter with respect to margarine price is −0.15, whereas the estimated cross-elasticity of margarine with respect to butter price is 0.89.[9] Apparently butter is a weak complement with margarine, but margarine is a strong substitute for butter. Qualitatively similar results were obtained by Goddard and Amuah and by Cox. The asymmetry in response is not surprising given that butter in Canada is nearly twice as expensive as margarine, which implies a larger income effect when the price of butter increases, *ceteris paribus,* than when the price of margarine increases. (For an alternative but more intricate explanation, see Pitts and Herlihy.)

Advertising and Information Effects

Because advertising effects are modeled as slope shifters, the advertising coefficients represent the change in the price coefficient with respect to a change in advertising. The butter advertising coefficient, as shown in table 1, is positive and significant in the butter equation, meaning that as butter advertising increases (decreases) the demand for butter becomes less (more) price elastic. Given that the butter ads made direct comparisons between margarine and butter, stressing the flavor and health attributes of the latter (Archie MacDonald, Dairy Bureau of Canada, personal communication, 1989), the finding that increased levels of butter advertising reduces the demand elasticity for butter is consistent with Quilkey's hypothesis. It is also consistent with the finding by Chang and Kinnucan that shows a decline in the own-price elasticity for butter following the commencement of butter advertising by the DBC in 1978.

The estimated coefficient of the cholesterol information index is significant in the case of butter and salad oils (table 1). The signs of the respective coefficients (negative for butter and positive for salad oils) agree with a priori expectations. In particular, the negative coefficient for butter indicates that as scientific knowledge about the role of cholesterol in heart disease increases (and presumably as consumers become more aware of this knowledge) the demand for butter decreases, *ceteris paribus*. By

[6] A data appendix, containing sources, is available upon request from the authors.

[7] "Tracking data" refers to dollar expenditure estimates generated by private research organizations that monitor television, radio, and print media to determine the advertising investments of different companies.

[8] The assumption of price exogeneity was examined using an instrumental variable procedure described by Kmenta (p. 683). The results, however, were not as plausible as the SUR estimates. For example, own-advertising elasticities were negative for several of the commodities and price responses were very small, contradicting the notion that simultaneous equation bias causes demand elasticities to be understated (Theil, Wahl and Hayes).

[9] Consistent with the results obtained by Cox (p. 24), cross-price effects for commodities other than butter and margarine were insignificant and therefore were dropped from the estimating equations. However, the income effects of changes in these prices are retained in the model through the use of Stone's index to deflate expenditures (see Deaton and Muellbauer, pp. 61–62).

Table 1. Coefficient Estimates for Four Fats and Oils Products, Canada

Explanatory Variables	Butter	Margarine	Shortening	Salad Oil
Price				
Butter	−2.03	2.73		
	(−2.51)[a]	(3.51)		
Margarine	−0.39	−0.17		
	(−1.66)	(−0.66)		
Shortening			−0.36	
			(−2.02)	
Salad oil				−0.30
				(−2.17)
Advertising * price				
Butter	0.79	−0.15	−0.19	0.56
	(1.84)	(−1.37)	(−2.00)	(0.56)
Margarine	0.21	−0.75	1.37	−7.85
	(0.03)	(−0.56)	(0.66)	(−0.58)
Shortening	0.93	−0.15	0.57	−0.61
	(0.28)	(−0.16)	(0.40)	(−0.08)
Salad oil	0.18	−0.55	−0.21	0.38
	(2.74)	(−0.32)	(−0.08)	(2.63)
Information	−0.75	0.06	0.09	0.65
	(−3.89)	(0.32)	(1.39)	(6.63)
Total expenditure	1.83	3.43	2.00	1.67
Seasonality	(3.00)	(4.95)	(4.05)	(4.22)
Spring	−0.24	0.20	−0.19	0.22
	(−2.87)	(2.13)	(−2.84)	(4.07)
Summer	−0.19	−0.03	0.04	0.16
	(−2.00)	(−0.32)	(0.52)	(2.74)
Fall	−0.13	−0.12	0.08	0.16
	(−1.51)	(−1.29)	(1.11)	(2.90)
Intercept	0.08	−6.01	−2.00	−2.64
	(0.06)	(−3.76)	(−1.82)	(−3.01)
R^2	0.83	0.71	0.58	0.78
D-W	1.75	1.17	1.85	1.61

[a] Figures in parentheses are *t*-values.

Table 2. Estimated Price and Expenditure Elasticities

	Price Elasticity[a]				Expenditure Elasticity[a]
	Butter	Margarine	Shortening	Salad oil	
Butter	−0.74	−0.15			0.71
Margarine	0.89	−0.09			1.12
Shortening			−0.29		0.89
Salad oil				−0.10	1.43

[a] All elasticities are evaluated at sample means.

the same token, the positive coefficient for salad oils indicates an increase in demand for these products, *ceteris paribus*, as information about cholesterol increases. These results are consistent with the notion that whereas saturated fats (contained in butter) are unhealthy, polyunsaturated fats (contained in specific salad oils) can be beneficial to health. These results support the hypothesis that unfavorable information about product quality reduces demand for the product in question, while favorable information increases demand.

The statistical results showing no link between scientific knowledge about cholesterol and

margarine consumption suggest the substitution of margarine for butter has occurred for reasons other than health. The results also imply that information inimical to butter is not necessarily favorable to margarine. Apparently consumers interpreted the health information (perhaps correctly—see *Newsweek*) not as an endorsement for margarine but as an indictment against butter.

The Attribution Hypothesis

Attribution theory posits that consumers respond more strongly to negative information than to equal quantities of positive information. Because advertising and cholesterol information are measured differently, it is not possible to construct a rigorous test of the asymmetrical response hypothesis. However, some light can be shed on the issue if appropriate qualifications are made. In particular, an elasticity measure can be used to quantify and compare the responses to advertising and cholesterol information if it is understood that such a comparison is valid only for incremental changes in the level of each factor relative to the initial point of evaluation and that percentage increases in each variable do not necessarily imply equivalent increases in favorable or unfavorable information on a per unit basis.

Table 3. Estimated Advertising and Cholesterol Information Elasticities

Commodity	Advertising Elasticity[a]	Information Elasticity[a]
Butter	0.02	−0.29
Margarine	−0.0002	0.02
Shortening	0.002	0.04
Salad oil	0.08	0.55

[a] All elasticities are evaluated at sample means.

Bearing in mind the foregoing caveats, own-advertising elasticities and information elasticities, evaluated at mean data points, were computed for each commodity. Results show the information elasticities uniformly larger (in absolute value) than corresponding advertising elasticities (table 3). These results imply that incremental percentage increases in cholesterol information have a greater impact on the demand for butter and salad oils than similar incremental percentage increases in advertising expenditures.

Because cholesterol information is unfavorable in the case of butter, the observed asymmetry is consistent with attribution theory. The asymmetry in the case of salad oils in which cholesterol information and advertising are both shown to have a positive influence on demand, but with cholesterol information evoking a larger response, may be attributable to the greater credence value of information provided by health authorities *vis-à-vis* industry. This result is consistent with a variation of attribution theory which states that favorable information disseminated by disinterested sources is more effective than (the same or other) favorable information disseminated by sources with a vested interest (Engel and Blackwell; Mizerski, Golden, and Kernan).

A simulation experiment confirms inferences drawn from the comparison of the information and advertising elasticities with respect to the disproportionate influence of negative information. Specifically, the equation for butter in table 1 was used to simulate consumption under different scenarios for butter advertising and cholesterol information as indicated in table 4. Relative to the simulated level with "low" cholesterol information and no advertising, results show butter consumption increasing 5.6% when advertising is increased to its end-of-sample (highest observed) level (table 4). Increasing cholesterol information to its end-of-sample level, by contrast, shows butter sales decreasing

Table 4. Simulated Butter Sales for Alternative Levels of Advertising and Cholesterol Information, Canada, 1985

Advertising	Cholesterol Information	Estimated Butter Sales	Difference
($ mil.)	(no. of articles)	(lbs./person)	(%)
0[a]	310[a]	11.51	
2.85[b]	310	12.15	+5.6
0	769[b]	8.70	−24.4
2.85	769	9.35	−18.8

[a] Beginning-of-sample (1974) levels of the respective variables.
[b] End-of-sample (1985) levels of the respective variables.

24.4%.[10] Thus, for butter it appears that negative information over the sample period was about four times more potent than positive information in influencing consumption behavior. This result corroborates a test of attribution theory by Richey, McClelland, and Shimkunas, who found that one instance of negative information can neutralize five instances of positive information. The magnitude of the simulated "cholesterol effect," roughly consistent with the results obtained by Brown and Schrader for shell eggs, highlights the potential importance of health information in modeling demand for some food items.

Concluding Remarks

This study examined the roles of cholesterol information and advertising in explaining consumption trends for fats and oils, focusing on butter. Results suggest increased consumer awareness of the health effects of blood cholesterol has contributed to the secular decline in butter consumption in Canada. Yet, despite the growing presence of unfavorable information, the industry advertising campaign launched in 1978 (and still in place) was shown to have had a positive effect on butter demand.

Thus, it appears that positive information, even when provided by industry, can have an impact in markets exposed to negative information. This suggests that commodity promotion programs established in part to provide a mechanism for responding to negative publicity can be effective. But, because consumers' responses to negative information may outweigh their responses to positive information (as suggested in this study), managers of such programs may want to consider strategies (e.g., product redesign, sanitation, inspection, quality control) that would minimize the probability of exposure to negative information in the first place.

Consistent with the findings by Brown and Schrader, this study suggests plausible price and expenditure elasticities can be obtained using variables to indicate the effects of health and other information on food demand. The significance of the cholesterol variable in the butter and salad oils equations suggests health information is relevant for understanding food consumption behavior and constitutes a potentially important avenue for improving the specification of empirical demand models.

[Received February 1990; final revision received November 1990.]

References

Albion, M., and P. Farris. *The Advertising Controversy: Evidence on the Economic Effects of Advertising*. Boston: Auburn House Publishing Co., 1981.

Armbruster, W., and G. Frank. "Generic Agricultural Commodity Advertising and Promotion: Program Funding, Structure, and Characteristics." *Generic Agricultural Commodity Advertising and Promotion*, ed. W. Armbruster and B. Wills. Agr. Extens. 88-3, Cornell University, March 1988.

Bronsard, C., and L. Salvas-Bronsard. "On Price Exogeneity in Complete Demand Systems." *J. Econometrics* 24(1984):235–47.

Brown, D., and L. Schrader. "Information on Cholesterol and Falling Shell Egg Consumption." *Amer. J. Agr. Econ.* 72(1990):48–55.

Chalfant, J., and J. Alston. "Accounting for Changes in Tastes." *J. Polit. Econ.* 96(1988):391–410.

Chang, H., and H. Kinnucan. "Advertising and Structural Change in the Demand for Butter in Canada." *Can. J. Agr. Econ.* 38(1990):295–308.

Clarke, D. G. "Econometric Measurement of the Duration of Advertising Effect on Sales." *J. Mktg. Res.* 13(1976):345–57.

Cox, T. L. "A Rotterdam Model Incorporating Advertising Effects: The Case of Canadian Fats and Oils." *Commodity Advertising and Promotion*, ed. H. Kinnucan, S. R. Thompson, and H.-S. Chang. Ames: Iowa State University Press, forthcoming.

Deaton, A., and J. Muellbauer. *Economics and Consumer Behavior*. London: Cambridge University Press, 1980.

Engel, J. F., and R. D. Blackwell. *Consumer Behavior*, 4th ed. Chicago: Dryden Press, 1982.

Feldman, S. "Motivational Aspects of Attitudinal Elements and Their Place in Cognitive Interaction." *Cognitive Consistency*, ed. S. Feldman. New York: Academic Press, 1966.

Goddard, E. W., and A. K. Amuah. "The Demand for Canadian Fats and Oils: A Case Study of Advertising Effectiveness." *Amer. J. Agr. Econ.* 71(1989):741–49.

Hanemann, W. M. "Some Further Results on Exact Consumer Surplus." Dep. Agr. and Resour. Econ. Work. Pap., University of California, Berkeley, 1982.

Hirschleifer, J. "Where Are We in the Theory of Information?" *Amer. Econ. Rev.* 63(1973):31–39.

Jastram, R. W. "A Treatment of Distributed Lags in the Theory of Advertising Effect on Sales." *J. Mktg. Res.* 13(1976):345–57.

Kanouse, D. E., and R. L. Hanson, Jr. "Negativity in Evaluations." *Attribution: Perceiving the Causes of Behavior*, pp. 47–62. Morristown PA: General Learning Press, 1971.

[10] Actual per capita butter consumption over the sample period (1974–85) declined from 13.00 to 9.01 pounds, or 31%. Results in table 4 showing a 24% decline associated with the increase in cholesterol information alone hint at the importance of health concerns in explaining consumption trends for selected foods.

Kinnucan, H. "Demographic Versus Media Advertising Effects on Milk Demand: The Case of the New York City Market." *Northeast. J. Agr. and Resour. Econ.* 15(1986):66–74.

——. "Evaluating Advertising Effectiveness Using Time Series Data." *Research on Effectiveness of Agricultural Commodity Promotion*, ed. W. J. Armbruster and L. H. Myers, pp. 112–13. Arlington VA: Farm Foundation and U.S. Department of Agriculture, 1985.

Kinnucan, H., and O. D. Forker. "Seasonality in the Consumer Response to Milk Advertising with Implications for Milk Promotion Policy." *Amer. J. Agr. Econ.* 68(1986):562–71.

Kmenta, J. *Elements of Econometrics*, 2nd ed. New York: Macmillan Publishing Co., 1986.

Krugman, H. E. "Brainwave Measures of Media Involvement." *J. Advertis. Res.* 11(1971):3–9.

Lilien, R. P., and P. Kotler. *Marketing Decision Making: A Model Building Approach*. New York: Harper & Row Publishers, 1983.

Mizerski, R. "An Attribution Explanation of the Disproportionate Influence of Unfavorable Information." *J. Consumer Res.* 9(1982):301–10.

Mizerski, R. W., L. Golden, and J. B. Kernan. "The Attribution Process in Consumer Decision-Making." *J. Consumer Res.* 6(1979):123–40.

Nelson, P. "Advertising as Information." *J. Polit. Econ.* 82(1974):729–54.

Nerlove, M., and F. V. Waugh. "Advertising without Supply Control: Some Implications of a Study of the Advertising of Oranges." *J. Farm Econ.* 43(1961):813–37.

Newsweek. "Is Margarine No Better Than Butter?" 27 August 1990, p. 64.

Phlips, L. *Applied Consumption Analysis*. Amsterdam: North-Holland Publishing Co., 1983.

Pitts, E., and P. Herlihy. "Perverse Substitution Relationship in Demand Studies: The Example of Butter and Margarine." *J. Agr. Econ.* 33(1982):37–46.

Pollak, R. A. "Conditional Demand Functions and the Implications of Separable Utility." *S. Econ. J.* 37(1971):423–33.

Pope, R. D. "The Impact of Information on Consumer Preferences." *Research on Effectiveness of Agricultural Commodity Promotion*. ed. W. J. Armbruster and L. H. Myers, pp. 69–79. Arlington VA: Farm Foundation and U.S. Department of Agriculture, 1985.

Putler, D. S. "The Effect of Health Information on Shell Egg Consumption." Dep. Agr. and Resour. Econ. Work. Pap., University of California, Berkeley, 1987.

Quilkey, J. "Promotion of Primary Products—A View from the Cloister." *Aust. J. Agr. Econ.* 30(1986):38–52.

Ray, M. L., A. G. Sawyer, and E. C. Strong. "Frequency Effects Revisited." *J. Advertis. Res.* 11(1971):14–20.

Rethans, A. J., J. L. Swasy, and L. J. Marks. "Effects of Television Commercial Repetition, Receiver Knowledge, and Commercial Length: A Test of the Two-Factor Model." *J. Mktg. Res.* 23(1986):50–61.

Richey, M. H., L. McClelland, and A. Shimkunas. "Relative Influence of Positive and Negative Information in Impression Formation and Persistence." *J. Personality and Social Psych.* 6(1967):322–27.

Simon, J. L., and J. Arndt. "The Shape of the Advertising Response Function." *J. Advertis. Res.* 20(1981):11–28.

Smith, M. E., E. O. van Ravenswaay, and S. R. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii." *Amer. J. Agr. Econ.* 70(1988):513–20.

Swartz, D. G., and I. E. Strand, Jr. "Avoidance Costs Associated with Imperfect Information: The Case of Keptone." *Land Econ.* 57(1981):139–50.

Tandemar Research, Inc. "Report on the Butter and Cheese Advertising Awareness, Attitude, and Consumption Survey." Toronto, Ontario, Nov. 1989.

Theil, H. *Theory and Measurement of Consumer Demand*, vol. 2. Amsterdam: North-Holland Publishing Co., 1976.

Wahl, T. I., and D. J. Hayes. "Demand System Estimation with Upward-Sloping Supply." *Can. J. Agr. Econ.* 38(1990):107–22.

Weinberger, M. G., and W. R. Dillon. "The Effects of Unfavorable Product Rating Information." *Advances in Consumer Res.* 7(1980):528–32.

Quality Variation and Quantity Aggregation in Consumer Demand for Food

Julie A. Nelson

Viewing the problem of "quality" variation in consumer demand for food as a problem of valid aggregation over goods leads to new insights. The simple sum of physical quantities, used as the measure of demand in the "quality" literature, is found to be a theoretically arbitrary and potentially misleading measure of demand when goods are heterogenous. Alternative measures of demand derived from restrictions on quality variation, consumer preferences, or relative prices, are investigated. A hypothetical example illustrates the use of a Hicksian composite commodity assumption. The empirical as well as conceptual merits of the various measures are discussed.

Key words: aggregation over goods, demand for food, Hicksian composites, quality variation.

The usual assumption made about prices in a cross-section analysis of household food expenditures is that all households are facing the same prices; estimation of price elasticities of demand is commonly left to time-series researchers who get price information from intertemporal indices. Recently, however, there has been renewed interest in the potential of cross-section analysis for estimation of price elasticities of demand for food, especially when surveys collect data on both household expenditures for food items and on the physical quantities purchased. Because we all know that "price times quantity equals expenditure," division of observed expenditure by observed quantity would seem to give the lacking price observation. Some researchers (e.g., Timmer and Alderman, Timmer) have used this simple definition. Others (e.g., Deaton 1986, 1987, 1988; Cox and Wolhgenant) have recognized that such a calculated "price" may reflect not only differences in the prices facing households (over which they presumably have no control) but also differences in quality levels of the commodity (over which households may have considerable choice). A higher price paid for beef, for example, might reflect the purchase of steak rather than hamburger. None of these works, however, have considered that quality, in addition to complicating the definition of price for demand analysis, also complicates the definition of quantity. This paper seeks to remedy this oversight by setting out the theoretical issues involved in the definition of quantity, examining potential conceptual solutions, and giving a hypothetical example of the implementation of one conceptual solution.

The following section sets out the theoretical issues and points out the problems with current formulations. The third section puts the quality issue into an aggregation theory context and describes three possibilities for defining theoretically valid quantity aggregates. Because only the Hicksian composite commodity theorem leads to interesting implications for quality choice, the following section illustrates how analysis might proceed under this assumption. A hypothetical application to demand for poultry brings in real-world measurement issues and illustrates the implication of the earlier theoretical analysis. The empirical as well as conceptual advantages and disadvantages of the various assumptions and methods are evaluated in the concluding discussion.

Julie A. Nelson is an assistant professor of economics, University of California, Davis.

This paper was begun while the author was employed by the Division of Price and Index Number Research, U.S. Bureau of Labor Statistics.

The views expressed in this article do not represent an official position of the Bureau of Labor Statistics or the views of other Bureau staff members.

The author wishes to thank an anonymous *Journal* referee for many helpful comments.

The Issues and Problems

As a convention, "elementary goods" in this paper will refer to goods which are strictly homogenous, and the quantity of purchases of any such good will be denoted by x_i. The term "commodities" will refer to heterogenous goods, i.e., which vary in their characteristics. A composite commodity such as "bakery goods," for example, will cover a class of elementary goods (or distinct individual purchases) that vary in flavor, air content, fat content, freshness, convenience of packaging, etc. Because it is impossible to estimate price elasticities for every possible elementary good, some way must be found to aggregate measures of demand for these goods into measures of demand for meaningful composite commodities with corresponding meaningful price measures.

The first well-known discussions of the problems created for economic analysis by quality variation were by Houthakker and Theil in the early 1950s. The model they created, while accepted and adapted by Deaton (1986) and Cox and Wohlgenant, leads to several difficulties. Theil defines heterogenous commodity quantities as the sum of the physical quantities of elementary goods in the group (assumed to be measured in a common physical unit), and adds "quality" choice as a separate set of elements in the household utility function. That is, households are assumed to maximize

$$(1) \quad \text{Max } U(q_1, q_2, \ldots, q_G, \ldots, q_M, \nu_1, \nu_2, \ldots, \nu_G, \ldots, \nu_M) \quad \text{s.t.} \quad \sum_{G=1}^{M} p_G(\nu_G)q_G = Y,$$

where

$$(2) \quad q_G = \sum_{i \in G} x_i$$

is the physical quantity consumed of commodity G (i.e., of elementary goods in group G), ν_G is the corresponding "quality" defined as a vector of characteristics, p_G is a composite price which depends on composite quality, Y is household income, and there are M groups. Houthakker's model is similar, except that q_G is the physical quantity of a single good chosen from the group and ν_G is a scalar indicator of quality.

First and most important among the problems created by this model is an inherent ambiguity about how the quantities, q_G, relate to the "quantity demanded" of consumer demand theory. In contrast to standard demand theory, in which quantity demanded is a function of exogenous prices and income, in this model the choice of quantity is also dependent on quality choice.

Second, the use of such physical quantities involves a selection of one dimension of physical measurement from a long list of possibilities. Physical quantity can be measured by weight, volume, protein content, caloric content, number of dietitian-identified portions, or by simple counts (as in dozens of eggs or heads of lettuce), to name just a few of the more common possibilites. The choice is trivial only for a homogenous commodity. For example, if consumers buy more dense, rich Häagen-Dazs ice cream as income rises and less of the air-filled store brand, the income elasticity of physical demand in terms of volume could be negative, even if the income elasticity of physical demand in terms of weight is positive. So is ice cream a luxury or necessity? Measurement in different physical quantity dimensions could suggest contradictory answers.

Third, it is unclear, without further assumptions, how these q_G's relate to any item of real interest. Blaylock and Smallwood state that sums of physical quantities by weight are of more interest from a nutritional standpoint than are dollar expenditures (in a constant-price framework). In addition, farmers or agricultural policy planners may be particularly interested in physical quantities by weight. Yet, these statements rest on special assumptions about the form of quality variation. If, for example, quality variation is purely in the dimension of flavor, the nutritional argument has merit; but, if it includes dimensions such as protein content, then Blaylock and Smallwood's statement concerning nutrition is clearly false. Equal weights of steak and hamburger meat, for example, may have roughly equivalent nutritional content, but equal weights of hamburger and soup bones clearly would not. Equal dollar's worth of hamburger and soup bones, on the other hand, might be roughly equivalent nutritionally.

Finally, the model outlined in problem (1) is difficult to solve in its general form. Additional assumptions are required to make the model tractable on a theoretical, much less an empirical, level. Theil makes the assumption that the prices of all qualities within a group G move proportionally in order to get theoretical results. He claims that this can be easily generalized but makes no attempt to do so. Houthakker uses a

slightly less restrictive assumption on prices—the functions $p_G(\nu_G)$ are assumed to be linear in ν_G—but requires in addition that only one purchase can be made from each group. By Houthakker's definition, if a household purchases both steak and hamburger (or even two grades of hamburger), one must create distinct groups for both. This formulation clearly undoes most of the advantages of grouping in the first place.

"Quality" and Theoretically Valid Aggregation

The issue of quality can be put in terms of familiar insights from aggregation theory if we begin with a more general model of preferences defined directly over elementary goods. Suppose the consuming agent solves the problem:

$$(3) \quad \text{Max } U(x_1, x_2, \ldots, x_R) \quad \text{s.t.} \quad \sum_{i=1}^{R} p_i x_i = Y,$$

where the x_i ($i = 1, \ldots, R$), are physical quantities of the elementary goods and the p_i ($i = 1, \ldots, R$) are the corresponding exogenous prices (whose units are consistent with the measurement dimensions of the respective x_i's). Controlling for "quality variation," then, is equivalent to the problem of grouping the elementary goods, defining the composite commodity quantities, Q_G ($G = 1, \ldots, M$, each being a function of the x_i, $i \in G$) and defining corresponding composite commodity prices, P_G ($G = 1, \ldots, M$), so that solving the problem

$$(4) \quad \text{Max } U(Q_1, Q_2, \ldots, Q_G, \ldots, Q_M) \quad \text{s.t.} \quad \sum_{G=1}^{M} P_G Q_G = Y$$

is equivalent to solving the disaggregate problem. That is, one wants to create a smaller number of composite commodities ($M < R$) that can be treated as if they were single goods in all respects.

The requirements for such aggregation are stringent (Blackorby, Primont, and Russell; Deaton and Muellbauer). While either homogenous separability or strong separability with aggregators of the Gorman polar form is sufficient for treating allocation among Q_G's as dependent on only P_G's and Y, each composite commodity must be a positive linear homogenous function of its elementary goods if the product of the price and quantity indices is to equal group expenditure [as is implicitly assumed in writing the budget constraint in (4)]. Three cases are examined here: first, a degenerate case, second, a case in which homogenous separability is created entirely by restrictions on preferences, and third, a case in which homogenous separability is created by a condition on the behavior of within-group prices.

Case 1: A Degenerate Case

One possibility is to define Q_G as a simple, unweighted sum of physical quantities. That is, Q_G is defined as equivalent to $q_G = \Sigma_{i \in G} x_i$ [as in the Theil case, equation (2)], with the elementary goods within group G defined in some common unit. This approach involves an assumption that the x_i's are perfectly substitutable on a one-to-one basis. The consumer cares only about the total physical quantity and not about its composition; from the consumer's perspective, the commodity is homogenous. This, of course, would make any discussion of quality irrelevant. The consumer would choose to consume only the cheapest elementary good or would be indifferent (if within-group prices were equal). The corresponding P_G is simply the lowest p_i, $i \in G$.

To the extent that commodities are actually homogenous, or perhaps very nearly homogenous, this approach is not misleading. Timmer and Alderman use the assumption of no quality variation in their work on rice, corn, and fresh cassava in Indonesia. Only a greater institutional knowledge of the Indonesian food market would tell if their assumption of homogenous commodities is appropriate. Are multiple varieties of these commodities available, with price variations reflecting differentials in consumer valuation of the varieties? Or does everyone consume the same kind of rice?[1] Deaton (1986, 1987) and Cox and Wohlgenant clearly do not use the assumption of homogenous commodities to justify their use of the sums of physical quantities as the measure of demand because they

[1] Not only basic foodstuffs as rice may be potentially homogenous. Foods made up of combinations of other foods, such as canned fruit cocktail or canned beef stew, can be classified as homogenous (in the sense used here) if consumers perceive no difference from can to can.

explicitly allow for commodity heterogeneity elsewhere in their analyses.[2]

Case 2: Restrictions on Preference Alone

Imposing homogenous separability entirely by restrictions on preferences is possible but puts implausible restrictions on the consumer choice of quality. For exact treatment of the composite commodity like a single good without restrictions on prices, preferences must be weakly separable and within-group preferences must be homothetic. While weak separability may be a useful assumption, homotheticity of within-group preferences implies that within-group income-expansion paths are straight lines through the origin—or that group composition is independent of income. For example, the ratio of hamburger to steak must be the same for rich consumers as for poor, at constant prices. Obviously such a restriction would often be empirically rejected.

Even if one imposed this restriction, assumption of homogenous separability still does not justify the use (by Deaton 1986, 1987, 1988; Cox and Wohlgenant) of simple sums of physical quantities as measures of demand. The proper measure of demand for homothetic intragroup preferences is a quantity index, reflecting the value of a utility subfunction (see Deaton and Muellbauer, p. 130), and which, therefore, incorporates not only the specified quantity dimension of the good but all other aspects of the good which are relevant to consumer valuation.

Case 3: A Hicks' Composite Commodity Formulation

With restrictions on relative prices, on the other hand, one can get both a strict justification for use of composite commodities and a clear and nontrivial model of quality. Assume that within each group G, prices of all goods vary proportionally. That is,

$$(5) \qquad i \in G \Rightarrow p_i = P_G p_i^*,$$

where p_i^* is the "base" price of good x_i and P_G is the factor of proportionality common to all elementary goods in group G. Then, by the Hicks composite commodity theorem, a composite commodity is defined as

$$(6) \qquad Q_G = \sum_{i \in G} p_i^* x_i,$$

or a base-price weighted sum of physical quantities. The Q_G have corresponding prices P_G (which can be thought of as group-specific price-level indicators) and can be treated as if they are elementary goods. The model collapses to the one described by equation (4). The demand function for a composite commodity is

$$(7) \qquad Q_G(P, Y),$$

where P is the vector of P_G's. Because the P_G's are exogenous to the consumer, the elasticity of Q_G with respect to P_G is the desired own-price elasticity for commodity G. The elasticity of Q_G with respect to Y is the desired income elasticity.

In principle, the Hicksian composite commodity theorem does not require that goods be related in any way other than through their constant relative prices: popcorn and airplanes could be in the same grouping if their prices moved together. In thinking about broad price movements in food products, however, this criterion for grouping goods is not entirely implausible. Variations in the wholesale prices of cattle or wheat, for example (resulting from seasonal effects or transportation costs), could have downstream impacts on the prices of all varieties of beef and all varieties of bakery products. To the extent the price changes are proportional, the Hicksian grouping criterion might accord well with many of the more conventional food groupings derived from a viewpoint of common features in consumption, rather than common price movements. Because Theil also assumed proportional intragroup prices to make his model tractable, the Hicksian approach adds no additional assumptions relative to the older literature. The model, as expressed in equation (3), represents instead a return to a more general expression of preferences.

The Hicksian approach allows other expressions to be written in terms of P_G and Q_G. Expenditures on group G are

[2] The assumption of perfect substitutability is, however, made—and yet not made—in an article cited by Deaton and by Cox and Wohlgenant. Cramer writes that "If, from the consumers' point of view, the quantities of several goods can be sensibly added together, such goods belong to the same commodity," and that this "requires that the goods concerned are close substitutes . . . , but since price differentials need the support of other differences they are not identical" (pp. 351–53).

$$(8)\quad E_G \equiv \sum_{i \in G} p_i x_i = \sum_{i \in G} (P_G p_i^*) x_i = P_G \sum_{i \in G} p_i^* x_i = P_G Q_G.$$

"Unit values" can be calculated from some household surveys as

$$(9)\qquad V_G \equiv E_G / q_G = \frac{P_G Q_G}{q_G}.$$

These, in general, will not be exogenous to the consumer because they depend not only on the exogenous price level but also on the consumer's choices reflected in Q_G and q_G. They will be equal to the exogenous proportionality factors P_G only if $Q_G = q_G$, which can occur only if the base prices for all goods in group G are the same and can hence be factored out of the right-hand side of equation (6). Such identical base prices might reflect a truly homogenous good.

But what happens to quality? The aggregation view makes it clear that the "quantity/quality" distinction is a problem for the researcher, not for the consumer. The consumer is interested, not in pounds of "beef," but in purchases of pounds of particular types of beef: the x_i, not the q_G, are the arguments of the consumer's utility function. Breaking down the consumer's demand for a good into quantity and quality elements is a purely artificial exercise, perhaps interesting to the researcher for reasons other than measurements of elasticities of demand. However, if one adopts a Hicksian composite commodity model, the earlier literature on quality choice can be reinterpreted in a particularly clear way.

Because Theil's earlier approach and the Hicksian approach explained here overlap in the hypothesis of fixed "base" prices, one can follow Theil and Cramer in defining a quantity-weighted sum of elementary goods base prices as a measure of average quality within a group:

$$(10)\qquad \nu_G \equiv \sum_{i \in G} \left(\frac{x_i}{q_G}\right) p_i^* = \frac{\sum_{i \in G} p_i^* x_i}{q_G},$$

where as before $q_G \equiv \Sigma_{i \in G} x_i$. The larger the proportions of higher-priced goods in the consumer's purchased bundle, the higher the measure of quality. As will be illustrated in the next section, the definition of the relative quality of different bundles depends crucially on the dimension (e.g., weight, volume, calories) in which the physical quantity (q_G) is measured. That is, by choosing one of the many dimensions in which characteristics of the good can be measured as reflecting quantity, the researcher's measure of quality defined by equation (10) is a scalar indicator of the consumer's valuation of all the omitted characteristics in the purchased bundle.

By these definitions, and for some specified dimension for the measurement of physical quantity, the following hold as identities:

$$(11)\qquad Q_G = \nu_G q_G$$

$$(12)\qquad E_G = P_G \nu_G q_G$$

$$(13)\qquad V_G = P_G \nu_G.$$

Composite quantity is a quality-adjusted quantity measure; expenditure on a composite can be broken down into exogenous price, quality, and physical quantity components; unit value has both exogenous price and endogenous quality components.

The price and income elasticities of concern can be found by taking natural logarithms of these equations and differentiating with respect to the natural logarithms of P_G or Y. Denoting the elasticity of a variable X with respect to income by β_x, and with respect to price by Θ_x, the following relationships are implied (for any group G):

$$(14)\qquad \beta_Q = \beta_\nu + \beta_q$$

$$(15)\qquad \Theta_Q = \Theta_\nu + \Theta_q;$$

and, because $\partial \ln P / \partial \ln Y = 0$ and $\partial \ln P / \partial \ln P = 1$,

$$(16)\qquad \beta_E = \beta_Q,$$

$$(17)\qquad \Theta_E = 1 + \Theta_Q,$$

$$(18)\qquad \beta_\nu = \beta_\nu, \text{ and}$$

$$(19)\qquad \Theta_V = 1 + \Theta_V.$$

Equation (14) is interpreted as the price elasticity of demand being the sum of the physical quantity elasticity and the quality elasticity. Equations (16) and (17) imply that the definition of physical quantity and quality measures is not necessarily a prerequisite for derivation of price and income elasticities of the Hicksian composite: the elasticities of demand could also be derived directly from the corresponding expenditure elasticities.

In summary, while simple sums of physical quantities are adequate measures of demand for homogenous commodities and restrictions on preferences alone give a well-defined aggregate only if shares of the individual elementary goods

in heterogenous composites do not vary with income, the Hicksian composite commodity assumption permits aggregation of elementary goods consistent with freely variable choices across elementary goods with varying characteristics. Also under the Hicksian assumption, if one particular dimension is chosen to measure physical quantity, then a precise measure of commodity quality, which subsumes the consumer's evaluation of all other aspects of the goods contained in the bundle purchased, can also be defined. If goods are heterogenous, simple sums of physical quantities measure demand only for a single physical characteristic of the commodity, not demand for the commodity itself.

A comparison of the aggregation techniques used in empirically analyzing other sorts of demand data (besides the expenditure-and-physical-quantity household-level data with which this paper is primarily concerned) also illustrates that use of physical quantity as the measure of quantity demanded relies on special assumptions. In time-series work on non-food commodities, often only expenditures and price indices are observed, and an approximation to homogenous separability through restrictions on preferences is often assumed in order to justify aggregation. In this case, quantity is defined only implicitly, as the index derivable from dividing expenditure by the price index. That is, $Q \equiv E/P$ where P is an index such as the consumer price index for the commodity. A rearrangement of equation (8) shows that the Hicksian assumption yields an analogous equation for quantity: $Q_G = E_G/P_G$. On the other hand, $q_G = E_G/V_G$ [from equation (9)] and is analogous to these other quantity measures only if unit values are actually exogenous price measures (i.e., if quality effects are absent).

An Application of Hicksian Restrictions to Poultry Demand

A simple illustration demonstrates the mechanics of the Hicksian composite commodity formulation, and highlights the pitfalls that can arise from focusing only on unadjusted physical quantity measures or ignoring quality variation. Suppose we have data on a consumer's demand for the heterogenous commodity "poultry," with different combinations of price and income. Case 1 of table 1 shows that in a base situation the consumer purchases one small roasting chicken and fifteen pounds of chicken backs, with expenditures of \$10.00 and \$7.50, respectively. Total expenditure on the group, noted as E_G in the last section (from here on the "G" will be assumed to refer to "poultry," and will be dropped to simplify notation), is \$17.50.

The first problem is that quantities are reported in different dimensions. The hypothetical researcher whose results are given in columns (3) to (5) chooses to convert the "one small roasting chicken" observation to its approximate weight. As the U.S. Department of Agriculture has developed a 454-page manual for doing such conversions, the researcher finds that, on average, such a chicken weighs five pounds. In the common dimension of pounds, $x_1 = 5$ and $x_2 = 15$, in the notation of the last section, and q, the total physical quantity in pounds, is 20. Unit value (V) is total expenditure divided by total physical quantity, or \$17.50/20 = .88. Base prices (p_i^* in the notation of the theoretical exposition) are \$2.00 per pound for roasters and \$.50 per pound for the backs. In the base case, the quality measures in column (5) are identical to the unit value measures, by definition [equation (13) with $P = 1$].

Another hypothetical researcher, however, uses tables developed by dietitians which give the number of portions that can be derived from different quantities of raw poultry. If a normal-sized portion of roast chicken is one-half pound, but because of all the bones it takes a full pound of backs and necks to make a portion, this researcher's results will be those reported in columns (6) to (8). In this case, the base prices are \$1.00 per portion for roasters, and \$.50 per portion for backs.

Two (and in theory, infinitely more) quite different physical quantity and "quality" measures can describe the same purchases. The quality-adjusted quantity measure, however, does not depend on this choice of dimension. This measure, Q in the earlier notation, is appropriately deflated expenditure, which at base prices is the same as expenditure [equation (8) with $P = 1$]. This is shown in column (9).

Suppose, next, that if income rose by 10% this consumer would purchase more roasting chicken and less backs, as shown in case 2. As prices are constant, both the elasticity of expenditure and the elasticity of quality-adjusted quantity measure the income elasticity of demand at 2.7 (computed, using the ratio of log-differences formula for an elasticity, as [ln(23) − ln(17.5)]/.10). Poultry is a luxury good in this example. A use of unadjusted physical weight as the quantity measure, however, would sug-

Table 1. Hypothetical Example of Poultry Demand

	(1) Quantity	(2) Expenditure (E)	Using Weight (lbs.) (3) Quality (x_i, q)	(4) Unit Value (V)	(5) Quality (ν)	Using Standard Portions (6) Quantity (x_i, q)	(7) Unit Value (V)	(8) Quality (ν)	(9) Composite Quantity (Q)
CASE 1: "base" situation									
Roaster	1	$10.00	5			10			
Backs	15 lbs.	$ 7.50	15			15			
Total		$17.50	20	$ .88	$ .88	25	$ .70	$ .70	17.5
CASE 2: 10% higher income									
Roaster	2	$20.00	10			20			
Backs	6 lbs.	$ 3.00	6			6			
Total		$23.00	16	$1.44	$1.44	26	$ .88	$ .88	23.0
Elasticity w.r.t. Income		2.7	$\boxed{-2.2}$	4.9	4.9	$\boxed{.4}$	2.3	2.3	$\boxed{2.7}$
CASE 3a: 10% higher prices, no response									
Roaster	1	$11.05	5			10			
Backs	15 lbs.	$ 8.29	15			15			
Total		$19.34	20	$ .97	$ .88	25	$ .77	$ .70	17.5
Elasticity w.r.t. Price		1	0	1	0	0	1	0	0
CASE 3b: 10% higher prices, small response									
Roaster	9/10	$ 9.95	4.5			9			
Backs	15 lbs.	$ 8.29	15			15			
Total		$18.24	19.5	$ .94	$ .85	24	$ .76	$ .69	16.5
Elasticity w.r.t. Price		.4	$\boxed{-.3}$	.7	−.3	$\boxed{-.4}$	.8	−.1	$\boxed{-.6}$
Unit value			$\boxed{-.4}$			$\boxed{-.5}$			
CASE 3c: 10% higher prices, big response									
Roaster	1/2	$ 5.53	2.5			5			
Backs	15 lbs.	$ 8.29	15			15			
Total		$13.81	17.5	$ .79	$ .71	20	$ .69	$ .63	12.5
Elasticity w.r.t. Price		−2.4	$\boxed{-1.3}$	−1.0	−2.0	$\boxed{-2.2}$	−.14	−1.1	$\boxed{-3.4}$
Unit Value			$\boxed{1.3}$			$\boxed{16}$			

gest the contrary: its elasticity is -2.2 (computed as $[\ln(16) - \ln(20)]/.10$), implying an inferior good. Physical quantity by portion has a computed income elasticity of .4 using the same formula, implying a necessity. The solution to this dilemma of multiple proposed elasticities is to recognize that only the number 2.7 represents the income elasticity of demand for poultry. The other two numbers are elasticities for specific characteristics of the good. In each case, all attributes of the good not covered by the characteristic selected are relegated to the single index, quality. The numbers have been made up so that quality increases with income, by either index. As implied by equations (14) and (16), the sum of the income elasticities of demand for quantity and quality, by either dimension, sum to the income elasticity of expenditure of quality-adjusted-quantity.

In the income elasticity case, the equivalence of expenditure and demand elasticities should come as no surprise: even students in introductory econometrics classes are instructed to use the value of purchases rather than their units in order to adjust for quality (Studenmund and Cassidy). The extension of this intuition to the variable-price case perhaps has been overlooked. Although one cannot use simple expenditure, which itself depends on price, as the measure of demand for determination of price elasticities, the attractiveness of the Hicksian approach is that expenditure, properly deflated, is the appropriate measure of demand.

Case 3a in table 1 illustrates, as a reference, the results of a 10% increase in both prices, but with the consumption bundle unchanged relative to the base case 1. Increasing both prices by the same proportion, P, imposes the Hicksian constant relative price assumption. As percentage changes were calculated as log-differences (e.g., $\text{Ln}(p^1) - \text{Ln}(p^0)$), the P corresponding to a 10% increase is 1.1052 times the base. Expenditures and unit values rise, but everything else stays constant relative to case 1. The quality-adjusted quantity measure now differs from expenditure, and quality measures differ from unit values, as these are now being deflated by the new price level (or, equivalently, are still being measured at base prices).

In case 3b, the price increases lead to a small cutback in consumption of roasters. Comparing case 3b with case 1, the price elasticity of demand for poultry is $-.6$ [which is the price elasticity of expenditure, .4, less 1; see equation (17)]. Elasticities of the physical quantity and quality measures with respect to the true (10%) price change are similarly negative but are only half to two-thirds as large. The price increase has led to some economizing on quality (by whatever measure), but unit values still rise with price. The equivalences set out in equations (15), (17), and (19) can be confirmed (except for rounding error).

The approach that yields the price elasticities of physical quantity with respect to the true price change is analogous to the approach taken by Cox and Wolhgenant in their study of U.S. demand for vegetable commodities and by Deaton (1986, 1987, 1988) in his study of demand for several food commodities in the Ivory Coast. As in the example here, these researchers separated out the true price variation information contained in unit values from the changes in unit values caused by quality variation. However, their measures of demand are the sums of physical quantities. These measures may not be invariant to measurement in another physical dimension, as can be seen in a comparison of columns (3) and (6).

The last line of case 3b gives the elasticities of physical quantity that would be calculated if a Timmer and Alderman approach were followed, that is, one ignored possible quality variation and treated changes in unit values as changes in prices. In this particular example, the elasticities of physical quantity with respect to unit values [e.g., in column (3), $\partial\ln(q)/\partial\ln(V) = -.3/.7 = -.4$] are in the same range as the other physical quantity and quality-adjusted quantity elasticities.

Case 3c shows that the convergence of the variety of elasticities to within a relatively small range in case 3b may be only fortuitous. If roaster purchases are cut in half following the price rise, the effect on the quality composition of the bundle is dramatic enough to lead to a drop in unit values. In this case, a study of the responsiveness of physical quantities to unit values would lead to the conclusion that poultry has a positive own-price elasticity, in the case of portions, of $+16$ (computed as the ratio of -2.2 to $-.14$)!

Conclusion

The main theoretical result of this paper, that rigorous and nontrivial definitions of aggregate quantities and of quality variation can be maintained only under Hickson composite commodity theorem assumptions, is cold comfort to the empirical researcher. While one might simulate

the assumption of constant relative prices in an experimental study or perhaps approximate it in a carefully specified study of some local market, it is unlikely that constancy of relative prices would hold either intertemporally or spatially for many goods in such much-used datasets as the Nationwide Food Consumption Survey. Results of a study applying the Hicksian assumptions to U.S. Consumer Expenditure Survey data can be found in Nelson (1987, 1990) but are somewhat unsatisfactory both in terms of the precision of the estimates and in terms of the specifications used to derive them.

Besides suggesting new research explicitly designed to incorporate the theoretical assumptions, a few conclusions can be drawn concerning current research. First, the importance of properly adjusting for quality variation depends on the importance of quality effects in the data under examination. It may very well be, for example, that rice is a fairly homogenous commodity in Indonesia, and, hence, Timmer and Alderman's treatment of demand for rice using physical quantities and unit values was theoretically appropriate (abstracting from empirical problems of measurement error). It might also be that, even when commodities are heterogenous, the composition which consumers choose might be relatively insensitive to changes in income or prices, again easing the problem of aggregation. More research put into measuring the degree of heterogeneity of a commodity, and the responsiveness of the composition of commodity aggregates to prices and income, could shed light on the appropriateness of aggregation methods used in past research. Empirical estimates of the income elasticities of physical quantity and of expenditure, which can often be easily obtained, can be compared in order to indicate the importance of quality effects. Second, methods and results devised by researchers who have sought to control for quality variation in the measurement of price, while using unadjusted physical quantities as the measure of demand, can be reinterpreted as measuring demand for one particular characteristic of the commodity, rather than for the commodity itself. For some applications, this might be sufficient, although the limitations of the approach and the possibility of getting different estimates if a different physical dimension were chosen should be noted. The old adage, "You can't add apples and oranges" is still true; the Hicksian approach adds the coda: unless the physical quantities can be weighted by unchanging base prices.

[Received September 1989; final revision received February 1991.]

References

Blackorby, Charles, Daniel Primont, and R. Robert Russell. *Duality, Separability and Functional Structure: Theory and Economic Applications*. New York: North-Holland Publishing Co., 1978.

Blaylock, James R., and David M. Smallwood. *U.S. Demand for Food: Household Expenditures, Demographics, and Projections*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Tech. Bull. No. 1713, Feb. 1986.

Cox, Thomas L., and Michael K. Wohlgenant. "Prices and Quality Effects in Cross-Sectional Demand Analysis." *Amer. J. Agr. Econ.* 68(1986):908–19.

Cramer, J. S. "Interaction of Income and Price in Consumer Demand. *Int. Econ. Rev.* 14(1973):351–63.

Deaton, Angus. "Estimation of Own- and Cross-Price Elasticities From Household Survey Data." *J. Econometrics* 36(1987):7–30.

——. "Quality, Quantity, and Spatial Variation of Price." Research Program in Development Studies Work. Pap. No. 127, Woodrow Wilson School, Princeton NJ, Nov. 1986.

——. "Quality, Quantity, and Spatial Variation of Price." *Amer. Econ. Rev.* 78(1988):418–30.

Deaton, Angus, and John Muellbauer. *Economics and Consumer Behavior*. Cambridge: Cambridge University Press, 1980.

Hicks, J. R. *Value and Capital*, 2nd ed. Oxford: Oxford University Press, 1946. (Cited in Deaton and Muellbauer.)

Houthakker, H. S. "Compensated Changes in Quantities and Qualities Consumed." *Rev. Econ. Stud.* 19(152–53):155–64.

Nelson, Julie A. "Quantity Aggregation and Price Variation in U.S. Consumer Demand for Food." Washington DC: U.S. Bureau of Labor Statistics Work. Pap. No. 168, June 1987.

——. "Quantity Aggregation in Consumer Demand Analysis When Physical Quantities Are Observed." *Rev. Econ. and Statist.* 72(1990):153–56.

Studenmund, A. H., and Henry J. Cassidy. *Using Econometrics: A Practical Guide*, p. 39. Boston: Little, Brown & Co., 1987.

Theil, H. "Qualities, Prices and Budget Enquiries." *Rev. Econ. Stud.* 19(1952–53):129–47.

Timmer, C. Peter. "Is There Curvature in the Slutsky Matrix?" *Rev. Econ. and Statist.* 63(1981):395–402.

Timmer, C. Peter, and Harold Alderman. "Estimating Consumption Parameters for Food Policy Analysis." *Amer. J. Agr. Econ.* 61(1979):982–87.

U.S. Department of Agriculture, Agricultural Research Service. *Manual of Food Codes and Weights for Use in Household Food Consumption Phase of the 1977–78 Nationwide Food Consumption Survey*. Washington DC, 1977.

Animal Stocking Under Conditions of Declining Forage Nutrients

Ray G. Huffaker and James E. Wilen

This paper examines the bioeconomic conditions under which the recently popular intensive-early-stocking (IES) strategy outperforms the conventional season-long-stocking (SLS) strategy as a response to the deterioration of forage nutrients over the latter stages of the grazing season. The economic performances of the IES and SLS strategies are compared to a dynamically optimal grazing policy that continually fine tunes stocking rates to account for declining forage nutrients. The comparisons yield a range of qualitative properties under which the IES strategy tends to approximate better the optimal strategy, some of which are investigated in a numerical illustration.

Key words: bioeconomic, intensive early stocking, season-long stocking.

In recent years a significant switch has occurred in spring stocking practices from the conventional season-long-stocking (SLS) strategy to the intensive-early-stocking (IES) strategy, particularly in the Midwest (Henderson, Kester, Morrow, Quigley). The SLS strategy maintains the same number of animals over the entire grazing season. However, research completed by grazing specialists suggests that, under certain conditions of deteriorating nutrients, substantial yield gains may be achieved by "tilting" the stocking pattern toward the early part of the season. The IES strategy attempts to cash in on these yield gains by doubling the conventional season-long-stocking rate for the first half of the season and then resting the pasture with no stocking as forage nutrients begin to play out. The apparent viability of the IES strategy raises interesting questions regarding the conditions under which IES-adoption makes economic sense.

This paper takes the following approach in determining the economic conditions favoring IES-adoption. First, the paper formulates a standard of performance, i.e., a dynamically optimal stocking (OS) policy that accounts for the nutritive deterioration of forage. Next, the paper discusses the interplay among economic and biophysical parameters that causes the "first-best" OS policy to be better approximated by the IES strategy as a "second-best" policy than by the SLS strategy. Finally, the paper illustrates this interplay with a comparison of the economic performances of the SLS and IES strategies to that of the OS policy on a representative Tennessee tall fescue pasture over a wide interval of pasture conditions.

Optimal Stocking Strategies in a Bioeconomic Model

This section first develops a single-season bioeconomic grazing model that provides the foundation for a multiseason version. Specifically, a Noy-Meir ecological grazing model is modified by incorporating deteriorating range conditions (within seasons) and interseasonal forage dynamics (between seasons). The biophysical model is embedded in a nonautonomous linear control framework that produces a closed-form analytical solution in simplified circumstances, but that requires numerical methods to produce the solution under the more generalized circumstances investigated in the body of the paper. The optimal "first-best" stocking patterns that emerge as solutions to this problem are useful in characterizing the bioeconomic conditions favoring adoption of an intensive-early-grazing (IES) stragegy as the "second-best" response to declining forage nutrients.

The Single-Season Model

Consider first the modified Noy-Meir ecological grazer/forage interaction model. Let $F_t \geq 0$ be

Ray G. Huffaker is an assistant professor, Department of Agricultural Economics, Washington State University; James E. Wilen is a professor, Department of Agricultural Economics, University of California, Davis.

the forage density at time t (state variable, lbs. dry matter [dm]/acre [ac]), and $S_t \geq 0$ the animal stocking rate at time t (control variable, head [hd]/ac), where t = days. The year is divided into a grazing season lasting T days and a dormant period lasting the remaining s days. During the grazing season the forage grows on average each day according to

$$(1) \qquad \dot{F}_t = G(F_t) - C(F_t)S_t$$

(equation of motion, lbs. d.m./ac/t), where $G(F_t)$ represents average daily plant growth at time t, $C(F_t)$ represents average daily consumption of forage by animals at time t (lbs dm/hd/t), and (1) is assumed to remain stationary over time. The initial forage stock, $F(0) = F_0$, and the terminal stock, $F(T) = F_T$, are given. Following the arguments of other workers (Noy-Meir 1975, 1978; Caughley 1976, 1981; Caughley and Lawton) the logistic equation is used to represent average daily forage growth over the grazing season,

$$(2) \qquad G(F_t) = aF_t - bF_t^2,$$

and the Michaelis-Menten function is used to represent the feeding function,

$$(3) \qquad C(F_t) = qF_t/(F_t + K),$$

where q is the maximum (satiation) daily consumption rate per animal and K is the "Michealis constant" measuring the forage level at which animals are half-satiated each day.

Finally, each animal's daily weight gain $W(F_t)$ (lbs/hd/t) is assumed to be initially proportional to its periodic consumption. Then, at some point in the grazing season $\tau \in [0, T]$, $W(F_t)$ is assumed to decay exponentially because of the deteriorating nutritive value of the forage stock

$$(4) \qquad W(F_t) = \epsilon_t C(F_t),\ \epsilon_t = \begin{cases} m & t < \tau \\ me^{-\delta t} & t \geq \tau \end{cases},$$

where m is the forage conversion parameter and δ is the constant rate of decay of nutritive value.

Consider now the producer's economic problem. The producer must allocate an exogenously determined initial inventory of animals between pasture grazing and the next best feeding alternative, e.g., dry-lot feeding. This focus shifts attention away from the market dynamics of the overall animal investment decision (Rosen) and allows the model to focus on the complexities of optimal stocking under deteriorating forage nutrients. The producer further is assumed to face a perfectly elastic demand curve for livestock output.

Let p be the price per pound of weight gain (\$/lb), and c_1 the average daily cost per head of grazing livestock on pasture (\$/hd/t). Then, the daily net revenue from stocking S_t animals on pasture is $[pW(F_t) - c_1]S_t$.

Animals removed from pasture are assumed to be placed on on-farm dry-lot feeding. Let ADG be the average daily gain on feed (lbs/hd/t), c_2 the cost of feed (\$/lb), ADC the average daily consumption on feed (lbs dm/hd/t), c_3 the average daily nonfeed costs per head of dry-lot feeding (\$/hd/t), i.e., veterinary expenses, and S^{max} the maximum stocking rate occurring when the entire inventory of animals is placed on pasture. Then, the daily net revenue from dry-lot feeding $S^{max} - S_t$ animals is $[pADG - C_2ADC - c_3][S^{max} - S_t]$.

Finally, let c_4 be the average daily cost per acre of maintaining the pasture (\$/ac/t). Then, the flow of net revenues (\$/ac/t) from both of the above activities is

$$(5) \qquad \begin{aligned} \pi(t) &= [pW(F_t) - c_1]S_t + [pADG \\ &\quad - c_2ADC - c_3][S^{max} - S] - c_4 \\ &= [pW(F_t) - c]S_t + \pi_{fd}S^{max} - c_4, \end{aligned}$$

where $\pi_{fd} = [pADG - c_2ADC - c_3]$ is the daily flow of net revenue from dry-lot feeding per animal (\$/hd/t); thus, $c = c_1 + \pi_{fd}$ is the sum of the incidental and opportunity costs of stocking an animal on pasture.

The single-season bioeconomic problem is to select the time path of pasture stocking rates that maximizes (5), subject to the modified Noy-Meir grazing model (1)–(4) and upper and lower limits on the pasture stocking rate

$$(6) \qquad \max_{S_t} \int_0^T e^{-rt}\pi(t)\, dt$$

$$\text{s.t. } \dot{F} = G(F_t) - C(F_t)S_t$$
$$F(0) = F_0,\ F(T) = F_T, 0 \leq S_t \leq S^{max},$$

where r is the real daily discount rate.

This is a most rapid approach problem (MRAP) as discussed in Spence and Starrett. The present-valued Hamiltonian for this problem is

$$(7) \qquad \begin{aligned} H &= e^{-rt}\{[p\epsilon_t C(F_t) - c]S_t + \pi_{fd}S^{max} - c_4\} \\ &\quad + \lambda_t[G(F_t) - C(F_t)S_t] \\ &= e^{-rt}[p\epsilon_t C(F_t) - c - \lambda_t C(F_t)]S_t \\ &\quad + e^{-rt}[\pi_{fd}S^{max} - c_4] + \lambda_t G(F_t) \\ &= \sigma_t S_t + \lambda G(F_t). \end{aligned}$$

The costate variable, λ_t (\$/lb dm consumed), measures the marginal present value of the forage stock in t, and hence the opportunity cost

of consuming forage presently by marginally increasing the livestock density. The function $\sigma_t = e^{-rt}[p\epsilon_t C(F_t) - c - \lambda C(F_t)]$ is the switching function and is used to synthesize the following optimal stocking policy sequence:

$$(8)\qquad S = \begin{cases} S^{max} & \sigma > 0 \\ S^* & \sigma = 0 \quad t < \tau \\ S^{**} & \sigma = 0 \quad t \geq \tau \\ 0 & \sigma < 0 \end{cases}$$

The policy requires that the stocking rate be set at one of its extreme values when the switching function is nonzero. The policy calls for the interior or "singular" controls, S^* and S^{**}, during the time intervals when the switching function vanishes (the singular case), i.e.,

$$(9)\quad \text{(a)}\quad \sigma_t = e^{-rt}[p\epsilon_t C(F_t) - c - \lambda C(F_t)] = 0, \text{ or}$$

$$\text{(b)}\quad \lambda_t = [e^{-rt}/C(F_t)][p\epsilon_t C(F_t) - c].$$

The interior controls are determined as follows. First, solve for the singular forage path before and after deterioration. Along the singular path, $\sigma_t = 0$, implying that $\dot{\sigma}_t = 0$, or by (9)(b)

$$(10)\quad \dot{\lambda} = -e^{-rt}\{p(r\epsilon_t - \dot{\epsilon}_t) - [1/C(F_t)]^2[rcC(F_t) - cC'(F_t)\dot{F}\},$$

where $C'(F_t)$ denotes differentiation. The singular path also must satisfy the adjoint equation

$$(11)\quad \dot{\lambda} = -H'(F) = -\{e^{-rt}p\epsilon_t C'(F_t)S_t + \lambda_t[G'(F_t) - C'(F_t)S_t]\}.$$

Equating (10) and (11); substituting in (1) and (9)(b) for $\dot{F}$ and λ, respectively; and rearranging terms yields

$$(12)\quad G'(F_t) = r - \frac{pC(F_t)\dot{\epsilon}_t}{p\epsilon_t C(F_t) - c} - \frac{cG(F_t)[C'(F_t)/C(F_t)]}{p\epsilon_t C(F_t) - c}.$$

Equation (12) describes the singular forage path F^* ($t < \tau$) and F^{**} ($t \geq \tau$) which must be "tracked" by stocking $S = S^*$ ($t < \tau$) and $S = S^{**}$ ($t \geq \tau$) whenever $\sigma_t = 0$. The interpretation of (12) follows the "modified golden-rule" arising in many resource modeling situations; namely, that an interior control strategy is chosen to keep the stock "close" to the golden rule level, $G'(F) = r$, modified by terms measuring the impact of nonautonomous parameters (2nd term RHS) and stock-dependent relationships (3rd term RHS).

Substituting (2) and (3) for $G(F_t)$ and $C(F_t)$, respectively, yields a quadratic equation in F_t

$$(13)\quad F^2 + \zeta_1 F + \zeta_2, \text{ where}$$

$$\zeta_1 = -\frac{(a - r)(pq\epsilon_t - c) + bcK + p\epsilon_t \dot{q}}{2b(pq\epsilon_t - c)}$$

$$\zeta_2 = -\frac{rcK}{2b(pq\epsilon_t - c)}.$$

The equations for the singular path before and after deterioration are obtained by applying the quadratic formula to (13)

$$(14)\quad \text{(a)}\quad F^* = -.5\zeta_1 + \sqrt{\zeta_1^2 - 4\zeta_2} \quad (t < \tau)$$

$$\text{(b)}\quad F^{**} = -.5\zeta_{1t} + \sqrt{\zeta_{1t}^2 - 4\zeta_{2t}} \quad (t \geq \tau),$$

where F^* is a constant forage level and F^{**} is a time-dependent path.

The associated singular controls are determined by solving (1) for S_t and substituting in the singular forage functions (14) (a) and (b)

$$(15)\quad \text{(a)}\quad S^* = G(F^*)/C(F^*) \quad (t < \tau)$$

$$\text{(b)}\quad S^{**} = \frac{G(F_t^{**}) - \dot{F}_t^{**}}{C(F_t^{**})} \quad (t \geq \tau),$$

where $\dot{F}_t^{**}$ is [by (14)(b)]

$$(16)\quad \dot{F}^{**} = -.5\dot{\zeta}_{1t} + .25(\zeta_{1t}^2 - 4\zeta_{2t})^{-.5}(2\zeta_{1t}\dot{\zeta}_{1t} - 4\dot{\zeta}_{2t}).$$

In order to see the implications of (12)–(16), consider the special case where c, the sum of the incidental and opportunity costs of holding livestock on pasture, is zero (fig. 1). Equation (12) reduces to $G'(F_t) = r - \dot{\epsilon}/\epsilon$, and the singular path jumps from $G'(F^*) = r$ down to $G'(F^{**}) = r + \delta$ at $t = \tau$. Both sections of the singular path, F^* and F^{**}, are constant. The figure assumes for purposes of illustration that $F_0 < F^*$ and $F_T > F^{**}$.

Figure 1 shows the optimal stocking pattern consists of sequences of extreme controls ($S = 0$ or $S = S^{max}$) that adjust the forage levels to F^* and F^{**}, together with constant interior controls S^* and S^{**} that track F^* and F^{**}, respectively. The optimal solution would be to adjust stocking levels to precisely track F^* and F^{**}, if such adjustment were feasible. However, the restrictions on the pasture stocking rate set out in (6), $0 \leq S_t \leq S^{max}$, makes tracking precisely the singular stock infeasible. For example, since $S \geq 0$, jumping from $F(0)$ to F^* at period zero or from F^{**} to $F(T)$ at period T is impossible.

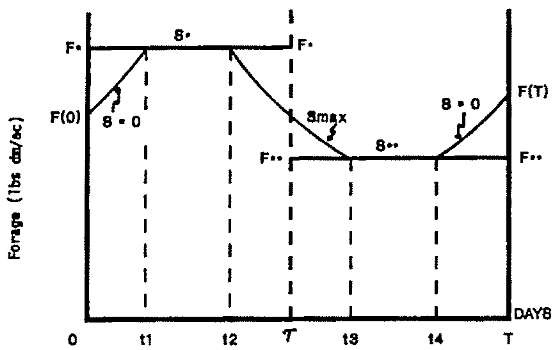


Figure 1. Optimal single-season stocking pattern (c =0)

Hence, the producer must postpone stocking until $t = t_1$, which is the time required for the forage stock to grow up to the singular level F^*. Similarly, the producer must terminate stocking at $t = t_4$ to allow the stock time to recover up to F_T. Moreover, because $S \leq S^{max}$ requires the stocking rate to be finite, the forage stock can not be instantly driven downward from F^* to F^{**} near period τ. Hence, the producer must determine the optimal time $t = t_2$ to begin stocking at the maximum rate, S^{max}, to drive the forage stock down from F^* to F^{**} by $t = t_3$. The optimal stocking pattern is not complete until the optimal switching times t_1 through t_4 are determined. In this simple case, all of the switching times can be determined analytically (appendix available from authors).

In the more general case ($c \neq 0$), the singular path continues to be constant before deterioration; however, after deterioration it becomes time dependent as in (14)(b). Whether the path is upward or downward sloping depends upon the parameters of the model. The significance is that the optimal stocking policy in the second half of the grazing season may involve continuously adjusting the number of animals according to S_t^{**} in order to track the time-dependent F_t^{**}. Moreover, some switching times can not be determined analytically, but require numerical methods.

Multiple-Season Model

In the single-season model both initial and terminal forage conditions [$F(0)$ and $F(T)$] were assumed to be given. In the more realistic multiple-season planning horizon, the forage density left on pasture at the beginning of the dormant period will have some impact on forage conditions the next grazing season. Hence, decisions should be linked across different seasons. The most straightforward assumption is that initial forage conditions in season $i + 1$ are proportional to terminal conditions in season i

$$(17) \qquad F^{i+1}(0) = \rho F^i(T),$$

where ρ is a proportionality constant and i indexes seasons. The more biomass left on the pasture at the end of the grazing season, the more will be available to initialize next season's forage growth.[1]

Given the proportionality and stationarity assumptions, the full multiple-season optimization problem is

$$(18) \qquad \max_{S_t^i} \sum_{i=0}^{\infty} \int_{i(T+s)}^{i(T+s)+T} e^{-rt}\{[pW(F_t^i) - c]S_t^i + \pi_{fd}S^{max} - c_4\}\, dt$$

$$\text{s.t. } 0 \leq S_t^i \leq S^{max}$$
$$\dot{F}_t^i = G(F_t^i) - C(F_t^i)S_t^i$$
$$F^{i+1}(0) = \rho F^i(T)$$
$$F^{i=0}(0) = F_0,$$

where T and s represent the duration of the grazing season and the dormant period, respectively. The multiple-season model is more formidable looking than the single-season problem, but it captures both within-season and between-season dynamics in a relatively simple manner.

The solution to the above problem can be approximated by solving a slight variant of the single-season problem. If there is a long-run steady state, the optimal stocking decisions will be repeatable over time, i.e., period i's terminal forage will determine period $i + 1$'s initial forage and so on, so that $F^{i+1}(0) = \rho F^i(T)$. Since the problem is linear, it is optimal to steer the system into this repeating pattern as quickly as possible. The optimal solution thus involves a sequence of repeated single-season optimal strategies in which the terminal (transversality) condition (or, alternatively the initial condition since they are proportional) maximizes the single-season present value,

[1] Characterizing between-season dynamics with a single parameter simplifies calculation of optimal interseasonal stocking paths considerably. A more detailed approach would include interconnected components for subsurface and above-surface biomass and account for density dependent effects in the forage and in the root mass. Because our focus is primarily on within-season dynamics, we abstract from these complexities and characterize between-season dynamics with a simple proportional relationship.

$$(19)\quad \max_{F(0)=\rho F(T)} \max_{S_t} \int_0^T e^{-rt}\{[pW(F_t) - c]S_t + \pi_{fd}S^{max} - c_4\}\, dt$$

$$\text{s.t. } \dot{F} = G(F_t) - C(F_t)S_t$$
$$F(0) = \rho F(T)$$
$$0 \leq S_t \leq S^{max}.$$

The repeatability of the multiseason solution incorporated into (19) avoids having to solve a complicated discrete control problem. This simplification essentially ignores some of the complicated transition dynamics associated with the complete problem in (18) and thereby reduces the problem to a "steady-state" problem parametric in $F(0)$. For each ($F(0)$, the stocking pattern is chosen that optimizes single-season present values, given that the terminal forage level $F(T)$ must be proportional to $F(0)$ via the dormant period transition relationship (17). The stocking pattern associated with the initial forage level yielding the largest single-season present value overall, F_0^{opt}, is the optimal repeatable pattern. A trade-off occurs here: other things equal, it is desirable to have a large $F(0)$ because early gains can be made by stocking large numbers of animals to reduce $F(0)$ to F^*. However, it costs something at the end of the grazing period to obtain this high $F(0)$; namely, one must refrain from stocking and place animals in dry-lot feeding earlier in order to allow forage to recover to a high value of $F(T)$ which, in turn, is necessary to generate high $F(0)$ in a repeating pattern.

A Comparison of First- and Second-Best Grazing Strategies

As demonstrated above, the optimal "first-best" policy involves a stocking profile that repeats each season and that, within each season, keeps the forage level "close" to the singular path. In contrast, the IES and SLS strategies can be viewed as "second-best" or "rule-of-thumb" solutions that approximate, to a greater or lesser degree, the first-best solution depending on the physical and economic parameters of the grazing system. The specific version of the SLS strategy considered is to hold the stocking rate constant at S^* (the optimal rate associated with $\delta = 0$) for the entire season, each season. Hence, the SLS strategy represents the extreme solution of ignoring the forage deterioration problem altogether. The specific version of the IES strategy considered incorporates the interseasonal proportionality restriction (17) so that it is a repeatable strategy like the other two. Hence, S^{max} is applied at the beginning of each season until midseason when stocking must cease completely for forage to recover to the level satisfying the proportionality restriction. The IES strategy represents the opposite extreme from the SLS strategy; namely, that the producer concentrates stocking in the portion of the grazing season when deterioration does not occur.

Consider now the interplay among economic and biophysical parameters that causes the optimal stocking policy to be better approximated by the IES strategy than by the SLS strategy. The IES strategy will best approximate the above trade-off made by the OS policy when the opportunity cost of refraining from stocking in the second half of each grazing season, i.e., the economic gain from late-season grazing, is low.

The economic gain from late-season grazing is inversely relate to $c = c_1 + \pi_{fd}$ in (5), where c_1 represents the average daily cost of grazing an animal on pasture, π_{fd} represents the daily flow of net revenue from dry lot feeding per animal, and hence c represents the sum of incidential and opportunity costs of stocking an animal on pasture. Late-season grazing gains are also inversely related to the forage nutrient deterioration rate, δ, which causes declines in animal productivity on pasture. Hence, the IES strategy becomes an increasingly better aproximation of the OS policy with *ceteris paribus* increases in c (resulting from either increased holding costs of animal on pasture or increased net revenues available from dry-lot feeding); and/or δ.

The IES strategy also becomes an increasingly better approximation of the OS policy with *ceteris paribus* increases in the proportionality constant, ρ, in (17). Increased ρ indicates that the initial forage stock of one grazing season is an increased proportion of the terminal stock of the previous season, i.e., there is decreased deterioration of forage stocks over the dormant season. Hence, less recovery time is needed at the end of the season for the forage stock to increase up to the terminal level required to sustain the repeatable stocking pattern. The OS policy responds by calling for the maximum stocking rate for longer periods during the first half of the grazing season.

Numerical Illustration

As an example, the economic performances of the season-long-stocking and intensive-early-

stocking strategies are compared with that of the optimal stocking policy on a "representative" tall fescue pasture in Tennessee over a wide interval of deterioration rates. Cow-calf operations traditionally have predominated over stocker operations in Tennessee. However, over the last decade, overwintering and spring stocking of feeder steers has increased in importance as a means of overcoming the shipping stress problem involved with transporting Tennessee cattle to out-of-state feedlots (McLaren et al.).

Data

The *Livestock and Forage Budgets for 1990,* prepared by the Tennessee Agricultural Extension Service (TAES), provide the following information regarding overwintering and spring stocking of steers. Overwintering lasts from 1 October to 1 April (183 days) and takes a steer from 450 to 587 pounds, for an average daily gain of 0.75 pounds per head. The spring grazing season lasts from 1 April to 1 August (122 days) and takes the steer to 770 pounds, for an average daily gain of 1.5 pounds per head during this period. Nutrient requirement tables indicate that this rate of gain requires about 14.7 pounds of dry matter intake per day for a 600-pound animal and 16.5 for a 700-pound animal, for an average of 15.6 pounds of dry matter per day (National Research Council). These figures are used here to represent the average daily gain and consumption rate before forage nutrients begin to decline; hence, the forage conversion coefficient is calculated as $m = 1.5/15.6 = 0.096$ by (4). The average pasture stocking rate reported is 1 acre per head (TAES). The maximum stocking rate is set arbitrarily at twice this rate in the simulations, $S^{max} = 2$.

The price of beef in the budgets is $p = \$0.75$ per pound. The average daily cost per head of grazing livestock on pasture is $c_1 = \$0.242$, and the average daily cost per acre of maintaining the pasture is $c_4 = \$0.33$.

Animals removed from pasture to dry-lot feeding are assumed to continue toward the terminal weight of 770 pounds, which requires them to gain and consume at the same rates on feed and on pasture. Hence, average daily gain on feed is $ADG = 1.5$ pounds per head, and average daily consumption is $ADC = 15.6$ pounds of dry matter per head. The cost of high quality hay for feed is $c_2 = \$0.05$ per pound (Tennessee Department of Agriculture), and the daily nonfeed cost per head of dry-lot feeding is $c_3 = \$0.236$ (TAES).

The available forage yield data were collected from experimental plots of tall fescue at the Ames Plantation Experiment Station in Southwest Tennessee over the period 1980–83 (Fribourg). Forage growth was measured by clipping a given plot to a 2-inch stubble height every 21 days and then drying and weighing the forage samples. Total forage growth available for spring grazing in a given year was measured as the accumulated growth over the 122-day season. The four-year average accumulated growth was calculated as 12.748 pounds of dry matter per acre per day.

Using this information to determine the parameters of the forage growth function, $G(F)$, in (2) is problematic. Ideally, data would exist giving the growth rates, $G(F)$, associated with a wide domain of forage levels, F, within $0 \leq F \leq F^{cc}$, where F^{cc} = carrying capacity of pasture for forage. Then, the function $G(F)$ could be econometrically estimated. Unfortunately, the four-year average accumulated growth figure (12.748 lbs dm/ac/day) can be linked to only one forage stock, i.e., whichever stock is associated with the 2-inch stubble height. Since the 2-inch stubble height produces maximum growth (Burns and Chamblee), the associated forage level represents the maximum sustained yield stock. Moreover, Noy-Meir (1976) reports that a forage carrying capacity of 500 grams per meter squared (4,461 lbs dm/ac) is reasonable for highly productive pastures, e.g., tall fescue pastures in the Upper South (Chessmore). Hence, the maximum sustained yield stock is $F^{msy} = F^{cc}/2 = 2{,}230.5$ pounds of dry matter per acre, and the single observation provided by the data set is $[G(F), F] = [12.748, 2230.5]$. However, knowing that growth is zero at carrying capacity provides a second observation: $[G(F^{cc}), F^{cc}] = [0, 4461]$. Inserting these observations into growth function (2) forms the following two simultaneous equations:

$$(20) \quad 12.748 = (2230.5)a - (2230.5^2)b, \text{ and}$$
$$0 = (4461)a - (4461^2)b.$$

Solution of this system via Cramer's rule generates values of $a = 0.011431$ and $b = 0.00000256$.

The above forage data did not include quality measurements. Hence, expert consultation with the principal investigator of the project generating the data (Fribourg, Dep. Plant Sci., University of Tennessee, personal communication, 1988) was used to adapt secondary forage quality data (National Academy of Sciences) to Ten-

nessee tall fescue (McBride). These adaptations indicate that the percent of total digestable nutrients holds steady at 62%–65% over the first half of the season (April through mid-May), and then deteriorates from 62% to 52% over the latter half (mid-May through July, 61 days). Assuming that nutrients N_t decline exponentially over time from initial level N_0, i.e., $N_t = N_0 e^{-\delta t}$, the above figures produce a decay rate over the latter half of the season of $\delta = -(1/t)\ln(N_t/N_0) = -(1/61)\ln(52/62) = 0.0029$. The forage conversion parameter, m, in feeding function (3) is assumed to decay at this rate.

The forage yield data set also did not contain information necessary to determine parameter K in feeding function (3). Again following Noy-Meir (1976), a reasonable value for highly productive pastures is 20% of carrying capacity (F^{cc}), so that $K = .2(4462) = 892$. The proportionality constant ρ linking the terminal forage level of one season with the initial level of the next is fixed at one.[2]

Finally, the proxy used in this study for the nominal discount rate is the daily interest rate on AAA corporate bonds for March 1989 (*Federal Reserve Bulletin,* table A24), $r_{nominal} = 9.8\%/365 = .0268\%$. This rate represents the return from low-risk investments in the capital markets. The real daily discount rate (r) is calculated as $r_{nominal}$ less the daily percentage change in price from March 1988–89 (*Federal Reserve Bulletin,* table A52), $r = .0268\% - 5\%/365 = 0.0132\%$.

Results and Discussion

The season-long-stocking, intensive-early-stocking, and optimal stocking strategies are simulated for values of the forage nutrient deterioration rate, δ, increased toward the calculated value for Tennessee tall fescue (.0029) from values 1/10th as large (.00029) and 1/100th as large (.000029). Figure 2 shows that the second half-season singular forage path F^{**} shifts downward as the nutrient deterioration rate increases *ceteris paribus*. This shift suggests that

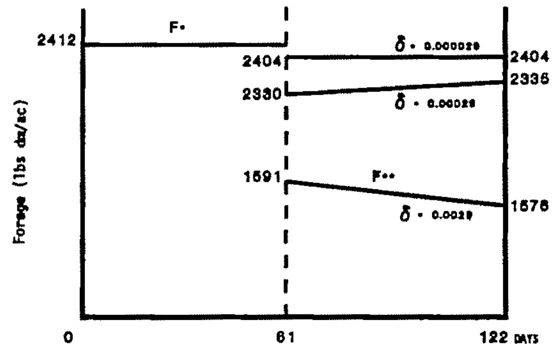


Figure 2. Simulated singular paths under various levels of forage deterioration

nutrient deterioration plays a role similar to depreciation in a capital model, increasing the impact of the discount rate and reducing the desired capital stock (forage) level (Clark, p. 74). The figure also shows that the lowest path monotonically decreases over time, while the higher paths monotonically increase. As stated above, the slope of F^{**} with respect to time depends on parameters. The numerical results indicate that the slope increases as the deterioration rate decreases for the underlying data set.

Figures 3a, b, c display the forage and stocking profiles corresponding to the different strategies as the nutrient deterioration rate δ is increased toward the calculated level.

In figure 3a, the deterioration rate is set at 1/100th of the calculated value for Tennessee tall fescue, $\delta = 0.000029$. This scenario involves only a slight deterioration of nutrients between the two halves of the season. The optimal stocking pattern is nearly constant over the season, with discrete stocking changes utilized only at the midpoint and end of the season to track the nearly flat optimal forage path.[3] The optimal stocking plan is thus qualitatively similar to the "golden rule" solution discussed after (12). In this application, the forage level is held close to the level at which the marginal productivity of the forage stock, $G'(F)$, is equal to the financial rate of interest, r, modified by the positive impact that forage density has on forage consumption [3rd term RHS of (12)].[4] By com-

[2] Selecting a reasonable value for ρ is problematic and depends on variable definitions. In the grazing model utilized in this paper, the forage stock F is measured in terms of above-ground biomass available to cattle. However, interseasonal dynamics are probably influenced more by subsurface biomass. We implicitly assume that forage density remaining at the end of a grazing season is an indicator of the density/quality of root zone mass. Root mass, in turn, determines available forage at the start of the next season (Stoddard, Smith, and Box, p. 107). For lack of empirical information and for ease of computation, we "normalize" by setting $\rho = 1$.

[3] Specifically, the OS strategy calls for a stocking rate $S^* = 1.1$ hd/ac to sustain a forage level $F^* = 2{,}412$ lbs dm/ac until the season's midpoint. Maximum stocking is then used for the one day necessary to drive the forage level to $F^{**}(t)$, which is then tracked until day 121. A one-day recovery period brings $F^{**}(t)$ up to F^*, and the pattern is repeated after the dormant period.

[4] Note that this forage density effect is strong enough that $F^* > F^{msy} = 2{,}230.5$ lbs dm/ac, where msy = maximum sustained yield.

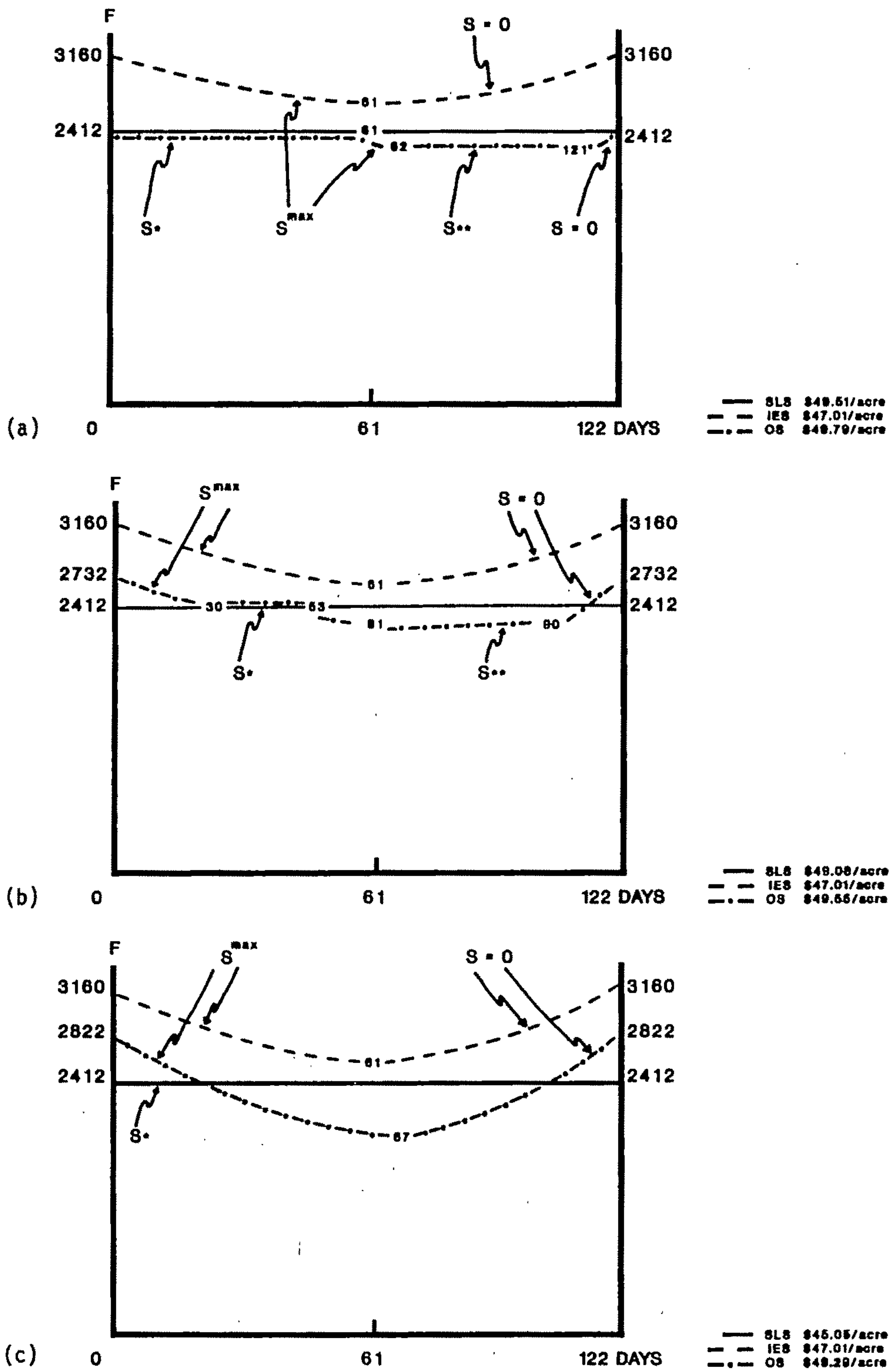


Figure 3. Comparison of simulated stocking strategies when ρ = 1; (*a*) δ = .000029, (*b*) δ = .00029, (*c*) δ = .0029, where *F* is forage (pounds dm/ac) and *S* is stocking rate (head/acre)

parison, the season-long-stocking strategy holds stocking and forage constant at the levels associated with the first half of the optimal plan, thereby ignoring the existence of forage deterioration. Because actual deterioration is close to zero in this case, the SLS strategy yields a present value close to the optimal policy (i.e., $49.51/ac vs. $49.79/ac).

In contrast, the intensive-early-stocking strategy overadjusts for the slight deterioration, and hence yields a smaller return ($47.01/ac). The IES strategy begins with a higher initial forage level (F_0 = 3160 lbs dm/ac) which is stocked at the maximum rate for half the season. Because the deterioration rate is slight, the IES strategy's departure from the nearly optimal SLS pattern does not pay off. Thus, simply ignoring the nutrient deterioration problem is the rule-of-thumb strategy that works best.

In figure 3b, the forage deterioration rate is set at a 1/10th of the calculated level for Tennessee tall fescue, $\delta = 0.00029$. The optimal stocking pattern associated with the two divergent singular paths is more complicated than the first case. In particular, because the opportunity cost of leaving forage at the end of the season is lower, animals are taken off pasture earlier, and the pasture is left to recover to a higher level. As a result, more animals can be grazed early in the next season over a longer period. Thus, the optimal stocking pattern calls for stocking at the maximum rate for thirty days, driving the initial forage F_0 = 2,732 down to F^*, at which point "normal" stocking is used to track F^*. Maximum stocking is then utilized again prior to the second half of the season to graze over the "blocked interval" during days fifty-three to sixty-one, driving the forage down to F^{**}. Optimal stocking in the second phase involves adjusting animals continuously until day ninety, at which point the pasture is allowed to recover.

The optimal stocking policy resembles the IES strategy more than the SLS strategy in response to the more substantial deterioration in the second half of the season. In terms of net present values, the SLS strategy is the better rule-of-thumb stocking plan because it yields nearly the same present value as the optimal strategy ($49.08/ac vs. $49.55/ac). The IES strategy overcompensates for the relatively small deterioration rate and consequently yields lower returns ($47.01/ac).

Finally, in figure 3c, the forage deterioration rate is set at the calculated value for Tennessee tall fescue, $\delta = 0.0029$. With a relatively high nutrient deterioration rate in the second half of the season, the payoff is less from holding cattle late into the season. Alternatively, there is a small opportunity cost associated with removing cattle, placing them on feed, and allowing the pasture to recover. This investment in next year's pasture allows more cattle to be stocked early in the season and held for a longer time. Thus, "tilting" pasture use toward the early season should become more profitable. The optimal strategy does indeed tilt pasture use toward the early season. Maximum profits ($49.29/ac) are achieved by using a maximum stocking rate for sixty-seven days and then removing the cattle to feed. The dormant period allows the initial forage to reach high levels (F_0 = 2,822), thus supporting the increased cattle density over a longer period.

The optimal strategy is more profitable than the SLS strategy ($45.05/ac). More important, the optimal strategy under this relatively high deterioration rate is qualitatively similar to the IES strategy. The IES strategy stocks at a maximum rate for half the season, yielding returns of $47.01 per acre. Thus, although the SLS strategy is the best rule-of-thumb approximation to the optimal strategy with low deterioration rates, the IES strategy becomes the closer approximation as the deterioration rates increases.

Concluding Comments

The motivation for this paper arises from the observation that a new pattern of stocking practices is apparently gaining increased favor in some parts of the country. While there are no data to verify the magnitude of the switch in practice, there is much anecdotal evidence in trade journals that intensive early stocking can be more profitable under certain circumstances than conventional constant season-long stocking. In addition, there are simulation-based studies and field measurements that have demonstrated the potential gains to be made by adopting the new practices, again, under specific circumstances.

This increased interest in the practice of, and the potential for, IES strategies raises some broad questions. One is, why are ranchers increasingly adopting these methods? A possible answer is simply information; that is, recent results of field tests by extension and range scientists may have popularized the potential of the practices and led ranchers to try them. It is equally possible that the impetus runs the other way, in that the practices have their origins in real commercial conditions and scientists are simply verifying their

potential under field plot conditions. A third possibility, and one that motivates this study, is that recent changes in biophysical and/or economic range conditions may have favored IES strategies *vis à vis* conventional SLS strategies. In exploring this possibility, one factor that stands out is the role of recent drought conditions and their impacts on forage deterioration. Thus, the paper investigates how a *ceteris paribus* increase in the nutrient deterioration rate might make IES a more attractive strategy.

The paper does this by developing a capital-theoretic model to characterize optimal within- and between-season use of a forage asset when productive (nutritive) value deteriorates over the grazing season. This approach departs from more common grazing/forage modeling in two ways. First, it goes beyond the pure simulation exercise to combine optimization-simulation techniques. Second, because the optimization problem is complicated, it relies on a purposefully stylized model that characterizes the problem with a relatively small number of variables, parameters, and functional relationships. Hence, the model's value is not in containing all the detail of a pure simulation model (although it is designed to be consistent with the underlying ecological principles) but rather in uncovering the qualitative properties that make the IES a more attractive rule-of-thumb strategy.

The central comparison in the paper is between the optimal (first-best) stocking policy and two second-best or rule-of-thumb strategies (IES and SLS). The optimization model characterizes the OS policy that continously tracks forage conditions and maximizes present values. The OS policy is then used as a benchmark to judge the relative closeness (in terms of present values) of the two rule-of-thumb strategies. The results of both the theoretical model and the numerical illustration suggest some interesting relationships between the qualitative properties of the first- and second-best strategies and the factors that affect their relative profitabilities. In particular, when nutrient deterioration (in conjunction with other bioeconomic conditions) is high during the second half of the grazing season, the IES strategy more closely approximates the optimal solution that tracks forage conditions continuously. In contrast, when nutrient deterioration is low, conventional SLS strategies outperform IES strategies. This relationship is consistent with the hypothesis that recent switches to early-intensive stocking may actually be optimal responses to range deterioration caused by repeated drought conditions and/or water shortages. Whether such switches are optimal in any given set of conditions depends upon the complicated interplay between biological and economic parameters. The model presented here structures those linkages in a manner sufficiently general to use under other circumstances.

[Received February 1990; final revision received November 1990.]

References

Burns, J., and D. Chamblee. "Changes in Quality and Chemical Constituents of Tall Fescue throughout the Growing Season at Various Degrees of Defoliation." *Proceedings of 29th Southern Pasture and Forage Crop Improvement Conference*, Clemson University, 16–18 May 1972.

Caughley, G. "What We Do Not Know About the Dynamics of Large Mammals." *Dynamics of Large Mammal Populations*, ed. C. W. Fowler and T. D. Smith. New York: John Wiley & Sons, 1981.

——. "Wildlife Management and the Dynamics of Ungulate Populations." *Applied Biology*, vol. I, ed. T. H. Coaker. London: Academic Press, 1976.

Caughley, G., and J. H. Lawton. "Plant-Herbivore Systems." *Theoretical Ecology*, 2nd ed., ed. R. M. May. Sunderland MA: Sinauer Associates, 1981.

Chessmore, R. *Profitable Pasture Management*, pp. 87–101. Danville IL: Interstate Printers and Publishers, 1979.

Fribourg, H. Unpublished data on forage productivity by soil series characteristic of West Tennessee, 1988.

Henderson, G. "Better Grass Gains with Intense Early Grazing." *Drover's J. Maga.*, March 1985, pp. 15–18.

Kestor, W. "Intensive Early Grazing Boosts Gains." *Beef*, July 1987, pp. 42–43.

McBride, B. *A Bioeconomic Simulation of Forage-Beef Systems Under Risk Considerations*. Ph.D. thesis, University of Tennessee, Knoxville, Aug. 1989.

McLaren, J. B., H. A. Fribourg, K. M. Barth, and J. M. Bryan. "Bermudagrass for Backgrounding Steers." *Tennessee Farm and Home Science*, pp. 45–48. Institute of Agriculture, University of Tennessee, Knoxville, 1979.

Morrow, R. E. "Choosing A Grazing System." *Beef*, Spring 1987, pp. 25–28.

National Academy of Sciences. *Atlas of Nutritional Data on United States and Canadian Feeds*. Washington DC: National Academy Press, 1972.

National Research Council. *Nutrient Requirements of Beef Cattle*, 6th rev. ed. Washington DC: National Academy Press for Subcommittee on Beef Cattle Nutrition, Committee on Animal Nutrition, Board on Agriculture, 1984.

Noy-Meir, I. "Rotational Grazing in a Continuously Growing Pasture: A Simple Model." *Agr. Systems* 1(1976):87–112.

——. "Stability of Grazing Systems: An Application of Predator-Prey Graphs." *J. Ecology* 63(1975):459–81.

Quigley, T. M. "Short-Duration Grazing: An Economic Perspective." *Rangelands* 9(1987):173–75.

Rosen, S. "Dynamic Animal Economics." *Amer. J. Agr. Econ.* 69(1987):545–57.

Spence, M., and D. Starrett. "Most Rapid Approach Paths in Accumulation Problems." *Int. Econ. Rev.* 16(1975):388–403.

Stoddart, L., A. Smith, and T. Box. *Range Management*, 3rd ed. New York: McGraw-Hill Book Co., 1975.

Tennessee Agricultural Extension Service. *Livestock and Forage Budgets for 1990*, pp. 18–19. Prepared by L. Johnson, Dep. Agr. Econ. and Resour. Develop., University of Tennessee, Dec. 1989.

Tennessee Department of Agriculture. *Tennessee Agriculture*. Nashville TN: Ellington Agriculture Center.

Producer Welfare Consequences of Regulating Chemical Residues on Agricultural Crops: Maleic Hydrazide and Tobacco

William E. Foster and Bruce A. Babcock

A procedure is presented to calculate welfare consequences of chemical regulation from demand curves when input applications are unobserved, and is applied to maleic hydrazide and tobacco. The relationship between chemical residues and weather variables and prices is estimated, and from this we derive demand curves using an application-residue relationship estimated using research station data. Chemical price levels required to attain given regulatory goals are estimated. Yearly producer losses from a chemical ban range from $6 million to $14 million, two to five times greater than from a tax achieving a 95% assurance rate of residues falling below a proposed standard.

Key words: agricultural inputs, chemical residues, welfare analysis.

Producer welfare effects of a price change resulting from a chemical's regulation are measured by the change in the area under the input demand curve (Just, Hueth, and Schmitz, pp. 58–59). In practice, however, such welfare analyses of chemical regulations are difficult because of the scarcity of data regarding chemical application rates and prices. Most empirical efforts have utilized information from natural scientists (entomologists, argronomists, etc.) to predict changes in marginal cost curves that result from regulation (e.g., Lichtenberg, Parker, and Zilberman).[1] The opinions of technical experts, however, do not reflect potential management responses of producers to change in market incentives. Calculations based on input demand curves estimated from producer data will give more accurate results, especially if the price changes caused by regulations are in the range of observed data.

This paper presents a procedure to calculate the welfare consequences of regulation from input demand curves when input application rates are not observed directly. Given a functional relationship, independent of price, between chemical application rates and chemical residue levels on harvested production, chemical input demand curves can be derived from estimates of the relationship between observed residues and prices.[2] This method is applicable to agricultural chemicals where data exist on residue levels or other indicators of use but where data on applications are sparse. Examples of potential applications include phosphate levels in waterways; contamination of groundwater; pesticide residues on imported food products, such as Mexican winter vegetables and some imported wines; hormone residues in beef; and sulfa residues in milk and meat. This analysis addresses the regulation of maleic hydrazide (MH) use on tobacco in North Carolina. MH residue data are available by growing region, allowing the esti-

William E. Foster is an assistant professor, Department of Agricultural and Resource Economics, North Carolina State University; Bruce A. Babcock is an assistant professor, Department of Economics, Iowa State University. Senior authorship is not assigned.

The authors would like to thank V. Kerry Smith, Gerald Carlson, Ray Palmquist, and the participants at the Agricultural Economics Workshop at North Carolina State University for their helpful comments. The residue data were supplied by Jack Sheets of the North Carolina Pesticide Residue Laboratory. The authors are grateful for this help and for his helpful comments on earlier drafts of this paper.

[1] One exception to this rule is Carlson's 1974 study of the welfare consequences of taxing various herbicides and insecticides.

[2] Another approach to estimating chemical derived demand curves which does not rely on input price and chemical use data is that of Babcock, Lichtenberg, and Zilberman. This approach derives a value of marginal product curve from observed data on chemical use rates, and the realizations of random yield and output quality.

mation of a regionally disaggregated model of welfare effects.

An Economic Model of Chemical Residue Levels

This section presents a conceptual model showing how economic incentives of producers affect residue levels of an agricultural chemical in the presence of random environmental effects, notably weather (namely, rainfall). The derivation of a residue-decreasing tax on the chemical is then demonstrated. This tax is derived from price-residue relationships, which are conditional on the realization of the random effects but which do not require an explicit functional relationship between chemical use levels and residue levels. Given an explicit relationship between chemical usage and residue levels, one can derive chemical users' willingness to pay to avoid the regulation.

Consider a representative producer, making input decisions, perhaps based on risk considerations. Over some time interval, t (perhaps a growing season), application decisions are based on the price of the regulated agricultural chemical, P_{mt}, prices of other inputs, P_{at}, and output price, P_{qt}. Random weather events may also influence chemical input decisions. For example, if preapplication weather is hot and dry, then certain pesticides may not be applied. In addition, chemical application rates may also depend on weather forecasts. At any time period t, per-acre levels of chemical applications for given prices and realized weather variables are given by the per-acre input demand for the chemical:

$$(1) \qquad X_t = X(P_{mt}, P_{at}, P_{qt}, w_t, H_t);$$

where w_t is the realization of a random weather variable, W_t, and H_t represents other nonprice variables, perhaps including forecast and other weather information.

Observed residue levels at time t, R_t, are positively related to application levels. They may also depend on post-application weather events. For MH, increases in post-application rainfall during the interval t, reduce residues for a given application level (USDA, 1979, Sheets and Nelson). Thus, residue levels depend on rainfall in period t and are not subject to economic incentives given application levels:

$$(2) \qquad R_t = R(X_t, w_t, R_{t-1}, Y_t);$$

where Y_t represents other pertinent information regarding the application-residue relationship, including weather-related variables other than W_t. In some cases, Y_t might represent time passed between application and residue level observation. Previous residue levels, R_{t-1}, are included for generality. In some cases (e.g., contamination of ground water or soil) residue levels are the result of past chemical applications. This application-residue relationship may be proportional or any monotonically increasing function of application levels.

Derived from (1) and (2), a reduced-form representation relates residue levels to prices and rainfall:

$$(3) \qquad R_t = G(P_{mt}, P_{at}, P_{qt}, w_t, R_{t-1}, H_t, Y_t).$$

Given a monotonic relationship, residues and chemical use respond similarly to changes in output and input prices. With the explicit relationship between chemical use and residue given by (2), one can recover the underlying demand expressed in (1) from the price-residue relation (3).

If residues are a monotonically increasing function of applications, an estimate of (3) allows the derivation of a tax that accomplishes a given regulatory goal. For example, suppose the regulatory agency seeks to reduce expected residues to a level Z. The tax is announced prior to the season, and rainfall is random from season to season, implying that the agency sets a tax rate T_0, such that

$$(4) \qquad E\{G[P_{mt}(1 + T_0), P_{at}, P_{qt}, W_t, R_{t-1}, H_t, Y_t]\} = Z;$$

where expectations are taken over W_t.

Alternatively, the regulatory agency could seek to reduce a season's residue level below Z with some probability π, greater than 50% ($\pi > .5$), and perhaps with certainty ($\pi = 1$). If, in (3), the reduced-form relation between residue levels and rainfall is negative, the tax rate T_1 that accomplishes this goal is found by

$$G[P_{mt}(1 + T_1), P_{at}, P_{qt}, w_{\pi t}, R_{t-1}, H_t, Y_t] = Z;$$

where $w_{\pi t}$ is such that $\mathrm{Prob}\{W_t > w_{\pi t}\} = \pi$.

If the relationship between per-acre application levels and residue levels is known, the welfare implications of regulations can be derived. The per-acre willingness-to-pay of the representative producer to avoid tax T_1 is given by the area under the demand curve (1) between P_m and $P_m(1 + T_1)$. The effects of a total ban on the

chemical's use can be determined by using a tax high enough to choke off demand altogether.

Efficient taxation should consider the regional response of residues to price changes. Region-specific taxes, however, are not practical if producers can purchase inputs in neighboring regions. Similarly, a ban on a chemical's use is typically national in scope. The following analysis considers a common regulation across regions.

The Use of MH in North Carolina Tobacco Production

The chemical MH is a systemic growth regulator. It is widely used in tobacco leaf production in the United States to control meristematic growth, called "suckers" (Hawks and Collins). Substitutes for MH are labor and other chemicals.[3] MH has been subject to regulatory scrutiny for over a decade due to human health considerations (USDA 1979).[4] Although to date no domestic regulatory constraints exist on MH residues on U.S. tobacco, other tobacco-producing countries restrict the chemical's use, and West Germany has established residue limits for tobacco products (Wittekindt). The West German MH restrictions, 80 parts per million (ppm) or less, are particularly important because West Germany is a major importer of U.S. tobacco leaf and products, and its regulations will influence the future harmonized regulations of the European Community. Currently, U.S. tobacco producers have no pecuniary incentive to control residue levels per se. Nevertheless, an unofficial goal of reducing MH residues below 80 ppm has been adopted by the U.S. tobacco industry (e.g., Sheets and Nelson). Ongoing efforts by the North Carolina Extension Service attempt to persuade growers to reduce residues below this level.

Growers use MH in all four North Carolina tobacco-growing regions, although residues vary significantly. The degree to which these residue differences reflect different production practices and different weather conditions is addressed below. From the period 1972 to 1988, residues averaged 124 ppm in the Eastern and Middle Belts, 112 ppm in the Border Belt, and 81 ppm in the Old Belt. Beginning in 1980, residue levels in the Eastern and Border Belts generally increased, while those in the Middle and Old Belts have trended downward. The variation in residue levels suggests large distributional effects from regulating MH use.

Economic Determinants of MH Residues on Tobacco

This section considers MH residues on North Carolina flue-cured tobacco and the sensitivity of residues to economic incentives. Data on average residue levels in the four growing belts were obtained from the North Carolina State University Pesticide Residue Laboratory for the years 1972 through 1988 (excepting 1973 and 1981). Average rainfall levels (in inches) for July (the month of greatest MH use) of each year were obtained for representative counties in each belt from North Carolina's Hydrologic Information Storage and Retrieval System. For each belt, the representative county rainfall levels are averaged for use in the analysis.

For a given growing belt in year t, the MH residue level is hypothesized to be a function of the price of MH, the price of an alternative growth suppressant, P_{ft}, farm labor wages, P_{lt}, the price of tobacco, P_{qt}, and July rainfall, w_t:

$$R_t = R\,[P_{mt}, P_{ft}, P_{lt}, P_{qt}, w_t, t].$$

The alternative chemical is a fatty-alcohol-based, new-cell killer that may replace MH altogether or be combined with MH. The manual removal of suckers is also a possible alternative to MH use.

Data on the per-gallon prices of MH and the alternative chemical are from statewide estimates of the North Carolina Agricultural Extension Service and the U.S. Department of Agriculture (1979). Chemical price data are unavailable for some years and are replaced by interpolations. Weekly labor wage data by belt are obtained from the North Carolina Employment Security Commission. Per-pound tobacco prices facing growers were constructed from data

[3] "Contacts" are a fatty alcohol-based chemical that kills developing suckers on contact. They must be applied directly on the suckers. Recently, a new chemical that gives local systemic control has gained popularity. It must be applied directly to the area of sucker growth. Often contacts and MH are used in a sequence of control: one or two contact applications precede one or two MH applications.

[4] In addition to tobacco production, MH plays a role in the storage of onions and potatoes, but has few other uses (USDA 1979, pp. 47–88).

obtained from the North Carolina Department of Agriculture and Toussaint.[5]

The functional form relating residue levels to the explanatory variables is determined by the nature of producer decision making and production technology (e.g., whether or not MH is an essential input), and by how well the functional form fits observed data. Prior knowledge suggests that tobacco can, and often is (e.g., in Canada), grown without MH. This suggests a functional form that gives zero residues at some finite price. This choke price could be estimated directly with a regression specification that allows a finite intercept. Unfortunately, regression analysis alone may yield unreliable predictions of out-of-sample quantities and residue levels at relatively high prices.

A choke price also can be estimated using other information besides the available price-residue regression data. One may select a functional form that best fits the data and then impose a choke price based on nonregression data if the regression-estimated choke price is unreliable.

Two functional form candidates are linear and log-linear specifications. A linear function imposes a finite choke price, whereas a log-linear form does not. Moreover, using only regression results, the log-linear form implies that MH is an essential input. Regression results for the linear function were less satisfactory than the log-linear functional form in that the own-price demand elasticity for MH was more inelastic than our prior beliefs based on expert opinions.[6] The log-linear form is used in the following discussion of the regression model and results where the choke price is estimated from additional information. For comparison, the regression results for the linear form are presented.

For estimation, region-specific residue functions (3) are considered linear in the natural logarithms of prices:

$$(5)\quad \ln r_t = k + a\cdot w_t + b\cdot \ln p_{mt} + c\cdot \ln p_{ft} + d\cdot \ln p_{lt} + f\cdot t + u_t,$$

where a, b, c, and d are estimable coefficients common across regions, k is a region-specific constant term, and f is a coefficient capturing region-specific unmodeled trends.[7] All prices are deflated by the per-pound price of tobacco facing growers, assuring zero-degree homogeneity of demand in prices.

A linear relationship is hypothesized between regional residue levels, R_i, and expected per-acre MH demand, X_i:

$$(6)\quad R_i = K(w)\cdot X_i\,(P_{mi}, P_{fi}, P_{li}).$$

The proportion K is assumed linear in total July rainfall with $K' < 0$.

In contrast to the price-residue relationship, K is estimated from regional field experiments on MH application at a specified rate under different rainfall levels. Resulting experimental regional residues, R_e, were regressed against rainfall. The null hypothesis of equal intercepts and slopes for all regions could not be rejected. Therefore, $K(w)$ is considered invariant among regions. The estimated equations (with t-statistics in parentheses) is

$$R_e(w)/X_o = K(w) = \underset{(7.86)}{63.195} - \underset{(2.18)}{2.82\cdot w}\qquad (R^2 = .23),$$

where X_o is the MH application rate used in the residue experiments.

Given a tax rate T to accomplish some regulatory goal, the expected per-acre welfare effect of the tax in region i, CS_i, is the expected area under the demand curve. Combining (5) and (6), and using the estimated function $K(w)$ results in

[5] The grower price of tobacco is not the observed market price paid by tobacco purchasers at auction. Total tobacco marketings are constrained by regulation, but growers can purchase and sell the right to market tobacco in any season. The per-pound value of this right to market is termed the quota rental rate. The effective price of tobacco facing growers equals the season-average market price less the average regional per-pound rental rates for poundage quota, and less the per-pound no-net-cost assessment (a regulatory fee). Thus, the price variables used in the regression can differ by region, even though the nominal prices are the same across regions. All data used in the analysis are available on request.

[6] The Box-Tidwell approach to distinguishing between log-linear and linear forms was inconclusive. Our prior beliefs are based on discussions with extension specialists for tobacco, and on anecdotal evidence from tobacco growers.

[7] MH residues may differ across regions for a number of reasons. The distinct soils and climates of the four growing belts can influence sucker growth. These differences should be captured in the intercept because they are constant over time. It is generally accepted that growers with larger operations use more MH for sucker control. This increased demand is caused by the higher incidence of mechanical harvesting on larger farms, which increases the payoff to sucker control, and to the greater difficulty in obtaining timely sucker control by manual methods. If the distribution of farm sizes has changed differentially over time across regions, then the regional differences should be captured in the trend term. Unfortunately, reliable data on farm size are not available.

$$(7)\quad CS_i(T) = E_w \int_{P_0}^{P_o(1+T)} X_i\,(P,\, w)\; dp$$

$$= E_w \int_{P_o}^{P_o(1+T)} [R_i\,(P,\, w)/K(w)]\; dp,$$

where P_0 represents the current MH price, P represents the vector of included prices, and E is the expectation operator. The function $CS(T)$ represents the maximum per-acre willingness-to-pay to avoid a per-pound MH tax rate of T.

Estimation Results

The four regional equations were estimated as seemingly unrelated regressions because of the high likelihood of common excluded variables. The Breusch-Pagen chi-squared test statistic (Judge et al., p. 476) under the null hypothesis of a diagonal covariance matrix is 18.76 with six degrees of freedom, implying that seemingly unrelated regressions are appropriate. The null hypothesis that the responses of MH residues to prices and rainfall were equal across the four belts could not be rejected at the .95 confidence level; therefore, the restrictions were imposed. The F-statistic for this test was 1.42 with 12 and 36 degrees of freedom. Differences across the growing belts are captured by belt-specific intercepts and the coefficient on the trend variable in each equation. Given that the price and rainfall responses are equal across belts, the null hypothesis of no differences in trend terms was rejected at the .99 confidence level with an F-statistic of 5.05 with 3 and 48 degrees of freedom. The regression results for the log-linear and linear functions are presented in table 1.

As expected, increases in the price of MH and July rainfall lead to decreases in residue levels. The log-linear elasticity of residue levels with respect to the price of MH is -0.7.[8] The estimated effect of July rainfall on MH residues implies that a 20% increase in rainfall from mean levels (5.2 inches for all belts) results in a 4.9% decrease in residue levels.

The positive cross-price elasticity of 0.34 for MH residues with respect to labor price indicates that growers substitute manual sucker control methods for chemical control. The positive

Table 1. Seemingly Unrelated Regression Results

	Log-linear Model[a]	Linear Model
Variable Name		
Price of MH	−0.705	−4.889
	(1.99)[b]	(1.57)
July rain	−0.0444	−5.002
	(2.99)	(3.46)
Price of labor	0.349	0.245
	(2.01)	(1.70)
Price of alternative	0.333	4.80
	(0.70)	(0.65)
Eastern Belt		
Trend	0.0020	4.06
	(0.79)	(1.30)
Constant	−35.60	−8041.1
	(0.78)	(1.27)
Border Belt		
Trend	0.0067	1.657
	(0.24)	(0.51)
Constant	17.23	−3173.7
	(0.34)	(0.48)
Middle Belt		
Trend	−0.0454	−2.153
	(1.37)	(0.54)
Constant	93.90	4372.2
	(1.59)	(0.56)
Old Belt		
Trend	−0.0628	−3.372
	(2.07)	(1.10)
Constant	127.81	6746.4
	(2.37)	(1.10)

[a] All variables were estimated in logs with the exception of *RAIN* and *TREND*.
[b] Estimated t-ratios are in parentheses.

coefficient, although statistically insignificant, on the price of the alternative chemical sucker control suggests that farmers may use more fatty alcohols to control suckers if the relative price of MH increases. The coefficient's insignificance may reflect the dual role of fatty alcohols as a substitute for MH and as a complementary input in a sequential regime of chemical control.

The trend variables account for unmodeled effects that have changed over time, such as relative changes in farm size in the growing belts. The trend coefficients in the Eastern, Middle, and Border Belts are not significantly different from zero, but the coefficient is significantly negative in the Old Belt. F-tests indicated that the null hypothesis that all four trend coefficients were zero was rejected at a 5% confidence level. Furthermore, the null hypothesis that the trend terms in only the Eastern, Border, and Middle Belt equations were all zero could also be rejected at a 5% confidence level.

These regression results suggest that the in-

[8] Few estimates of pesticide demand elasticities from time-series data are available in the literature for comparison. Carlson (1977, p. 546, table 4) estimates pesticide elasticities of approximately −1. See also Carlson (1974).

crease in observed MH residues on North Carolina tobacco can be attributed to two economic factors. First, the decline in the price of MH relative to the grower price of tobacco, from \$13.40 to \$3.52 over the sample, was a major contributor to increased residue levels. Indeed, the relative price of MH in 1959 was \$40 per gallon in 1988 prices (USDA 1962). Second, the cost of labor has also increased. Tobacco producers substitute away from expensive hand-suckering techniques by increased use of chemical control methods.

The expected response of residue levels to changes in the relative price of MH for the four growing belts is presented in figure 1. All other prices and the trend term are set equal to their 1988 levels. Only the Old Belt has expected residue levels below the 80 ppm level at the 1988 price of \$6.00 per gallon. Expected residues are 137 ppm in the Eastern Belt, 109 ppm in the Border Belt, and 101 ppm in the Middle Belt. The expected residue levels for North Carolina at different prices of MH are also presented in figure 1. This expectation is the weighted average of the four belt-specific expected residue levels with the weights given by the 1988 percentage of production in each belt. The expected residue level for North Carolina at the 1988 MH price is approximately 114 ppm, which is 42.5% above the 80 ppm standard. The relatively high state average residue level is the result of the Eastern Belt accounting for 51% of the state's tobacco crop.

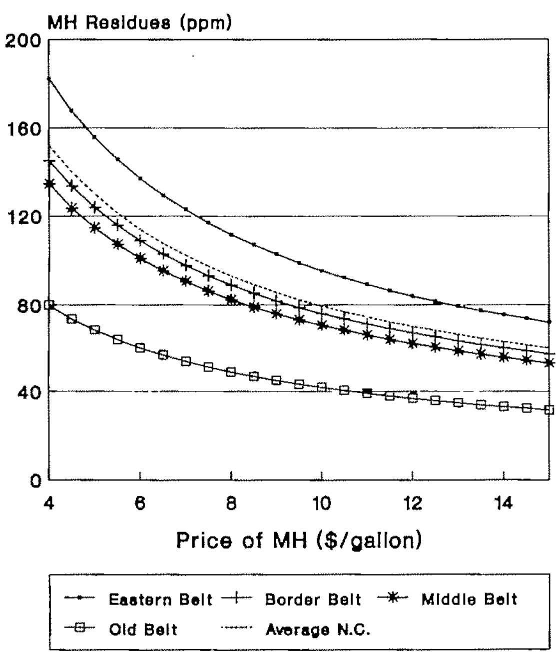


Figure 1. Expected MH residue levels by belt and North Carolina average

Increasing the Price of MH to Achieve Regulatory Goals

Two regulatory methods for reducing residue levels are to increase the price of MH by a per-unit tax or fee, and to ban its use. The tax is used to achieve a residue goal, while a ban eliminates residues altogether. Presenting the welfare costs of both regulatory methods shows the higher costs associated with a ban versus a tax. The extent to which residue levels will fall for a given tax depends on the price elasticity of demand for the chemical. The estimated own-price elasticity of MH residues is approximately −0.7 for the log-linear case. Given the hypothesized proportionate relationship between chemical applications and post-harvest residue levels (6), the elasticity of demand is equal to the price elasticity of residue response. As shown in figure 1, expected residue levels for North Carolina tobacco do not fall below 80 ppm until the price of MH rises to approximately \$10.00 per gallon. Even at this price, however, with a symmetric rainfall distribution, the chance that residues will be above 80 ppm is approximately 50%. To achieve a higher assurance rate would require a higher price. The probability that residues in North Carolina, R_{nc}, are below 80 ppm for a given price of MH, is given by

$$\text{Prob}\,(R_{nc} < 80) = \text{Prob}\left[\sum_{i=1}^{4} l_i R(w_i, P_m) < 80\right],$$

where l_i is the proportion of production coming from the ith growing belt. This probability is not equal to the weighted sum of probabilities that individual regional residues are less than 80 ppm unless the w_i are independent.

The joint distribution of July rainfall in the four North Carolina growing belts was obtained by first constructing a July rainfall variable for each growing belt. This was done by averaging rainfall data from representative counties for each belt for the period 1940 to 1988. Sample means, variances, and covariances were then calculated for the four rainfall variables. The joint rainfall distribution was obtained using these sample moments in a multivariate normal distribution. The null hypothesis of a diagonal covariance matrix of July rainfall between regions was rejected at the 1% level of confidence.

To calculate the probability that an average sample of North Carolina tobacco contains less residues than 80 ppm requires a probability distribution of North Carolina residues. There is no closed-form solution for this distribution function regardless of the choice of functional form for the rainfall distribution. The probability distribution of state residues is calculated by numeric methods using a sample of 5,000 joint normal rainfall deviates. For each rainfall draw, North Carolina average residue was calculated for the given price of MH.[9] The proportion of draws that resulted in residues falling below 80 ppm was taken as the regulatory assurance rate given a price of MH. Figure 2 shows the results of these simulations for various prices for both the log-linear and linear specifications. A price of $10.50 for the log-linear specification results in an assurance rate of 50% that residues will fall below 80 ppm, while a price of $14.50 results in an assurance rate of 100%. For the linear specification, a price of approximately $15.60 results in an assurance rate of 50%, while it takes a price of $21.00 to achieve residues below 80 ppm with certainty.

This illustrates the sensitivity of the assurance tax to the estimated price elasticity of residue. The estimated own-price elasticity of MH residues averaged over the four belts with the linear specification is −.35 at 1988 data. The more inelastic response given by the linear specification implies a considerably higher tax.

Welfare Consequences of Regulating MH

The loss in producers' expected welfare from taxing chemical use is measured by the change in the area under the demand curve for that chemical. Given the hypothesized proportional relationship between residue levels and applications rates, the expected welfare loss for the *i*th growing region is given by (7). The North Carolina average loss is the weighted average of the four regional losses. No consumer welfare losses arise from a tax on MH because, due to government supply restrictions, the consumer price is well above the marginal cost of production for all growing belts even when MH is banned.[10] Marginal costs must increase more than $300 per acre before any consumer losses would occur.

In the log-linear case, to achieve a 95% assurance rate that MH residues will be less than 80 ppm (requiring a tax of $6.50 per gallon over the 1988 price of $6.00 per gallon—see figure 2) imposes an average loss of $11.83 per acre. The distribution of losses ranges from approximately $14.36 per acre in the Eastern Belt to

[9] The estimated probabilities that MH residues will fall below 80 ppm are found by the "plug-in" method whereby estimated parameters are treated as the actual values. Considering estimation risk would give rise to different probabilities that residues are below 80 ppm and different estimates of welfare losses for a given price of MH.

[10] The producer losses reported here are the sum of the decline in the return to quota and the change in producer surplus. Babcock and Foster show that producer surplus may actually increase when an input price increases.

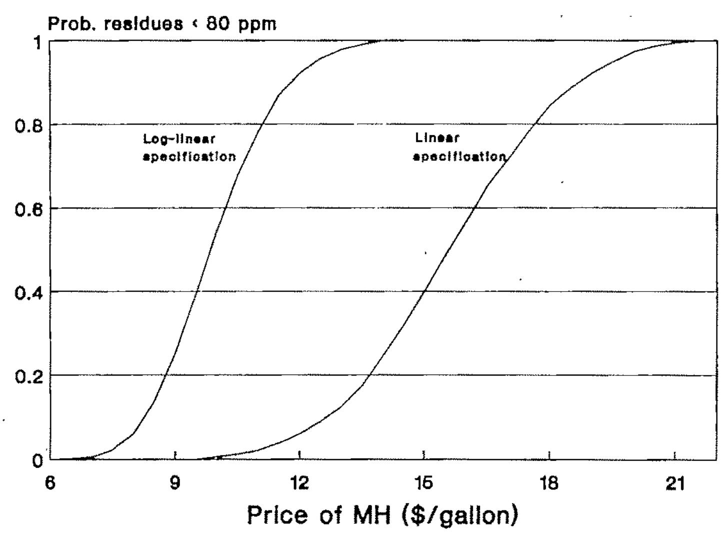


Figure 2. The probability of meeting a residue standard for different MH prices

$5.75 per acre in the Old Belt. The loss in the Old Belt reveals the inequality of welfare losses by region. The Old Belt, which falls below the 80-ppm standard without a tax, reduces its residues further under the tax scheme, allowing the Eastern Belt to exceed the 80-ppm limit with some probability. A more equal solution would impose region-specific taxes. Such a scheme is impractical due to the ease with which MH can be transported across regions.

The effect of a ban on the sale of MH can be calculated by increasing the MH tax to a point where the demand for MH is zero. The choke price for the log-linear case can be estimated in two ways. MH, introduced in the 1950s, was the first sucker control chemical available for tobacco. The only substitute available at that time was manual control. An approximation of an upper bound on the choke price for MH can be made by assuming (*a*) MH was monopolistically priced, (*b*) aggregate MH demand was linear, and (*c*) the marginal cost of producing MH is zero. Under these conditions price will be set where marginal revenue is zero, which implies that the linear demand curve intersects the price axis at twice the observed price. The price of MH in 1959 was $18.00 per gallon, suggesting a choke price of $36.00 per gallon in 1959 dollars. Adjusting this price by the relative price of tobacco in 1959 and 1988 results in an estimated choke price of $88.00 per gallon of MH in 1988 dollars. This procedure places an upper limit on the choke price. Since 1960, the introduction of substitutes for MH has undoubtedly decreased this maximum price.

Another choke price estimate can be obtained by assuming that only two technologies are available for growing tobacco: one with MH and one without. Discussions with tobacco production specialists indicate an approximately $100-per-acre loss from an MH ban. This loss includes $22 extra per acre for chemical and application costs and $78 per acre from yield losses. Implicit in this estimate is that growers would use the present level of MH up to some price, and then switch from MH to other practices. The $100 per-acre loss at the 1988 use rate of 2.35 gallons per acre and price of $6.00 per gallon is consistent with a $48.55 choke price: $48.55 = $100/2.35 + $6.00.

Table 2 presents the producer welfare losses from a ban on MH by region and for North Carolina as a whole for the log-linear and linear cases. With the log-linear specification three choke prices—$25.00, $48.55, and $88.00 per gallon—are included. In addition, table 2 presents the welfare losses from the imposition of a tax to achieve a 95% probability that average North Carolina residues are less than 80 ppm.

Banning MH imposes annual welfare costs ranging from approximately $6 million to $14 million.[11] For the log-linear specification, at the $48.55 choke price, the average per-acre welfare cost of a ban is $41.82. With the linear specification the average cost is $38.39 per acre. The log-linear specification implies that banning MH imposes approximately 3.5 times the welfare costs of the tax scheme. In contrast, the linear specification implies that a ban would result in 47% higher losses than the tax scheme. These estimates indicate that the estimated welfare costs of taxing a production input are much more sen-

[11] Possible long-term benefits of banning MH, which are not included in the producer welfare cost estimates, are the maintenance of export markets.

Table 2. Producer Welfare Costs of Regulating the Use of MH

Type of Regulation Specification[a]	Tax[b]		Ban			
			Log-linear with an assumed choke price of[c]			
	Log-linear	Linear				Linear
Welfare losses for:			25.00	48.55	88.00	
Eastern Belt	1,757,664	3,933,936	3,807,864	6,192,216	8,789,544	5,599,800
Border Belt	360,326	800,748	780,624	1,272,024	1,802,112	1,102,920
Middle Belt	513,576	1,219,680	1,111,320	1,810,368	2,564,856	1,673,280
Old Belt	207,000	302,328	468,360	763,200	1,081,440	837,720
North Carolina	2,838,556	6,256,692	6,168,168	10,037,808	14,237,952	9,213,720

[a] With the linear specification, the expected choke prices are $45.75 for the Eastern Belt, $35.35 for the Border Belt, $33.20 for the Middle Belt, and $23.27 for the Old Belt.
[b] The tax rates used for $6.50 per gallon for the log-linear specification and $13.50 per gallon for the linear specification. These rates result in a 95% probability that MH residues are less than 80 ppm.
[c] An assumed choke price is necessary because the estimated derived demand for MH does not intersect the price axis when a log specification is used.

sitive to the estimated demand elasticity than are estimates of the losses from banning the input.

Table 2 also demonstrates the regional disparity of welfare loss resulting from regulation. The welfare costs fall most heavily on the Eastern Belt, both on a per-acre and an aggregate basis. Finally, the estimated welfare costs from a ban are significantly less than the production experts' estimates of $100 per acre, which are based on zero substitution between MH and other sucker-control techniques.

Concluding Comments

This paper considers the welfare consequences of regulating agricultural chemical use based on the derived demand for chemicals as revealed by chemical residue, environmental, and price data. The method is applicable to other agricultural chemicals where data exist on residue levels or other indicators of use but where data on applications are sparse.

MH residues on North Carolina flue-cured tobacco respond to both economic and environmental factors. The estimated own-price elasticity of demand for the chemical was −0.7 using a log-linear form. Estimated cross-price elasticities of demand are 0.35 for hired labor and 0.33 for the chemical substitute. Increases in rainfall in the usual month of chemical application reduce residues at harvest.

The annual welfare losses to North Carolina from banning the chemical are a function of different choke prices. A reasonable range of total welfare losses is from approximately $6 million to $14 million per year. This range is two to five times as large as the welfare loss from an MH tax that achieves a 95% assurance rate of residues falling below the 80 ppm proposed standard, using a demand elasticity of −0.7. A more inelastic demand decreases the difference in welfare costs between a ban and a tax. The effects of regulating the use of MH differ by region. The producer welfare losses from a tax that achieves a 95% assurance rate range from $5.75 per-acre in the Old Belt to $14.36 per acre in the Eastern Belt.

[Received April 1990; final revision received January 1991.]

References

Babcock, B. A., and W. E. Foster. "The Distribution of Economic Rent Under Mandatory Supply Controls." Paper presented at AAEA annual meeting, Manhattan KS, 4–7 Aug. 1991.

Babcock, B. A., E. Lichtenberg, and D. Zilberman. "The Impact of Damage Control on the Quantity and Quality of Output: Estimating Pest Control Effectiveness." *Amer. J. Agr. Econ.*, in press.

Carlson, G. A. "Economic Incentives for Pesticide Pollution Control." *The Practical Application of Economic Incentives to the Control of Pollution: The Case of British Columbia*, ed. James B. Stephenson. Vancouver: University of British Columbia Press, 1974.

——. "Long-Run Productivity of Pesticides." *Amer. J. Agr. Econ.* 59(1977):543–48.

Hawks, S. N., and W. K. Collins. *Principles of Flue-cured Tobacco Production*. Raleigh NC: Hawks and Collins, 1983.

Judge, G. G., W. E. Griffiths, R. C. Hill, H. Lutkepohl, T.-C. Lee. *The Theory and Practice of Econometrics*, 2nd ed. New York: John Wiley & Sons, 1985.

Just, R. E., D. L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy*. Englewood Cliffs NJ: Prentice-Hall, 1982.

Lichtenberg, E., D. D. Parker, and D. Zilberman. "Marginal Analysis of Welfare Costs of Environmental Policies: The Case of Pesticide Regulation." *Amer. J. Agr. Econ.* 70(1988):867–74.

North Carolina Agricultural Extension Service. *Tobacco Enterprise Budgets*. Dep. Econ. and Bus., North Carolina State University, various years.

North Carolina Department of Agriculture. *North Carolina Agricultural Statistics*. Raleigh, various years.

North Carolina Employment Security Commission. *Employment and Wages in North Carolina*. Raleigh, various years, 1972–88.

Sheets, T. J., and L. A. Nelson. "Variation of MH Residues in Flue-Cured Tobacco." *Tobacco Sci.* 5(1989):42–45.

Toussaint, W. "Lease-rates for North Carolina Flue-cured Tobacco." Mimeographed. Raleigh: North Carolina State University, 1988.

U.S. Department of Agriculture, Economic Research Service. *Costs of Crop Production by Size of Farm: Central Cotton-Tobacco Area of North Carolina*. Agr. Econ. Rep. No. 14, Washington DC, 1962.

——. "The Biologic and Economic Assessment of Maleic Hydrazide." Tech. Bull. No. 1634, Washington DC, 1 Oct. 1979.

Wittekindt, W. "Recommended Plant Protecting Agents—Current Strategies in 22 Important Tobacco Exporting Countries." *Beitrage zur Tabakforschung Int.* 13(1986):271–80.

Providing Crop Disaster Assistance through a Modified Deficiency Payment Program

Mario J. Miranda and Joseph W. Glauber

Federal income support programs provide producers with only a limited degree of income protection in the event of a widespread crop failure. As an alternative to supplemental disaster assistance, we propose a modification of the deficiency payments program in which a producer's payment would be based on the difference between a target revenue and the average revenue in the producer's region. A regional target revenue progam would provide improved individual income protection without promoting moral hazard and would limit regional revenue shortfalls, thereby eliminating the demand for supplemental disaster assistance and reducing government costs.

Key words: deficiency payments, disaster assistance, revenue insurance, risk and uncertainty.

Much of the debate surrounding the 1990 farm bill focused on the best means of providing producers with income protection in the event of a widespread crop failure. The debate is not new. Prior to 1980, the U.S. Department of Agriculture (USDA) provided disaster assistance mainly through direct cash payments. Because of strong criticism that the disaster payment program was too expensive, restrictive in scope, and encouraged production in high-risk areas, Congress enacted the Federal Crop Insurance Act of 1980 to replace the disaster payment program with crop insurance as the primary means of providing catastrophic income protection to farmers.

The federal crop insurance program, however, has failed to perform as expected. Although the 1980 act authorized the Federal Crop Insurance Corporation to subsidize producer premium payments and to expand coverage, participation in the program between 1980 and 1988 never exceeded 25% of eligible acreage.[1] Adverse selection and moral hazard problems also seriously undermined the actuarial performance of the program and led to large government outlays (Chambers, Nelson and Loehman, Skees and Reed).[2] Most significantly, however, the federal crop insurance progam failed to eliminate federal disaster assistance. Because of the low rate of participation in the program, the federal government enacted supplemental ad hoc disaster assistance legislation four times between 1980 and 1989 in response to widespread yield shortfalls. The U.S. Government Accounting Office estimates that government disaster payments over that period exceeded $6.9 billion.[3]

The poor performance of the federal crop insurance program has raised serious concerns about whether a fiscally responsible crop insur-

The authors are, respectively, an assistant professor, Department of Agricultural Economics and Rural Sociology, Ohio State University, and an economist with the Economic Research Service, U.S. Department of Agriculture.

This research was supported by the U.S. Department of Agriculture Cooperative Research Agreement 58-3AEK-7-00035.

The views in this paper represent those of the authors only and do not necessarily reflect those of the U.S. Department of Agriculture.

The authors thank Sam Evans and Paul Westcott for helpful comments.

[1] While estimated participation in 1989 is 44%, much of the increase resulted from a provision of the 1988 Disaster Assistance Act that required producers to purchase crop insurance for 1989 in order to qualify for 1988 disaster payments (Glauber et al.).

[2] The General Accounting Office estimates that over the period 1980–88, government outlays for the federal crop insurance program exceeded $4.2 billion, accounting for over 80% of the total indemnities paid to producers.

[3] Supplemental disaster assistance legislation has significantly undermined participation in the crop insurance program. Many producers forego purchasing crop insurance in the belief that the federal government will provide supplemental disaster relief.

ance program could attract sufficient participation to reduce the demand for supplemental disaster legislation. Citing these concerns, the Bush administration has recommended replacing the federal crop insurance program with a standing disaster assistance program that would indemnify producers for individual crop losses whenever catastrophic losses are experienced at the county level (USDA 1990). Critics, however, have charged that the program would provide producers with insufficient protection at the low coverage levels that would be required to observe federal budgetary constraints. Proposed modifications to the current federal crop insurance program aimed at increasing participation also appear unattractive. Making crop insurance compulsory for loan program participants would be unpopular with producers. Providing free, fully subsidized crop insurance would involve large government outlays and would encourage risky production practices (Glauber, Harwood, and Miranda).

As an alternative to supplemental disaster assistance, we propose a modification of the current deficiency payment program that would provide improved income protection in the event of widespread crop failure. Under the current deficiency payment program, producers receive payments proportional to the difference between a target price and the higher of the market price or the nonrecourse loan rate. Although this method of payments provides protection against price drops, it offers little protection against the adverse effects of catastrophic yield shortfalls: in the event of a widespread crop failure, the market price rises, shrinking if not eliminating, the deficiency payment. Under the modified deficiency payment progam, a producer's payment would be based on the difference between a target revenue and the average revenue in the producer's region. Because yield and price are negatively correlated, deficiency payments would be higher under a target revenue progam than under a target price program when yields are low, thereby providing improved income protection in the event of a crop failure. More significantly, a target revenue program would place a high floor on regional producer revenues, thereby reducing, if not eliminating, the demand for supplemental disaster assistance and lowering overall government costs (Evans).

Because target revenue payments are based on regional rather than individual revenue shortfalls, a target revenue program is not a true individual income insurance program (Arzac, Offut and Lins, U.S. Congressional Budget Office, USDA 1983). A target revenue program, however, can offer effective protection against individual income risk because individual producer yields are generally correlated within a region. A target revenue program, moreover, is not prone to the moral hazard problems that typically undermine individualized insurance schemes. Moral hazard, which occurs when insured individuals alter their behavior in a manner that increases their chances of collecting an indemnity, leads to resource misallocation and actuarial losses for the insurer. Under a target revenue program, however, an individual producer cannot significantly affect aggregate revenue and, thus, the indemnity received. Accordingly, a target revenue program does not distort existing individual incentives to produce efficiently.

In the following sections, a regional simulation model of the U.S. corn market is used to compare producer revenues and federal budget outlays under the current target price deficiency payment program and under national, state, and county target revenue deficiency payment programs. The analysis indicates that for the same cost as the current target price program, a county target revenue progam for corn would substantially reduce county-level revenue variability and would also stabilize total government deficiency payments. The analysis also indicates that a county target revenue program would provide better individual income protection to corn producers than a target price program, even when the latter is implemented in conjunction with individualized crop insurance coverage such as is currently available through the Federal Crop Insurance program.

Regional Model of the U.S. Corn Market

Let Y_j denote the average yield obtained by corn producers in region j at harvest time. Denoting the program acreage planted to corn in region j by A_j^p, the amount of program corn produced in region j is

$$Q_j^p = A_j^p \cdot Y_j. \tag{1}$$

Denoting the nonprogram acreage planted to corn in region j by A_j^n, the amount of nonprogram corn produced in region j is

$$Q_j^n = A_j^n \cdot Y_j. \tag{2}$$

Total program corn production is, thus,

$$Q^p = \sum_j Q_j^p, \tag{3}$$

total nonprogram corn production is

$$(4) \qquad Q^n = \sum_j Q_j^n,$$

and total program and nonprogram corn production is

$$(5) \qquad Q = Q^p + Q^n.$$

The quantity of corn C that disappears for domestic and foreign consumption and for other private productive uses is a function of the market price for corn P:

$$(6) \qquad C = D(P).$$

Quantities of corn released by the government from its stockpile, denoted G^-, and quantities of corn acquired by the government, denoted G^+, alter the market supply-demand equilibrium. The supply of corn available on the market is composed of new production and government stock releases; conversely, available supplies of corn are either consumed or acquired by the government. This leads to a material balance relation:

$$(7) \qquad Q + G^- = C + G^+.$$

Government stock acquisitions and releases are governed by the provisions of the nonrecourse loan program. If the market price for corn P exceeds the loan rate for corn P_L, participating corn producers repay their loans and the government acquires no stocks:

$$(8) \qquad P > P_L \rightarrow G^+ = 0.$$

If the loan rate exceeds the market price, on the other hand, all participating producers default on their loans and the government acquires their output:

$$(9) \qquad P < P_L \rightarrow G^+ = Q^p.$$

If the release price for corn P_R exceeds the market price for corn P, the government releases no stocks from its stockpiles,

$$(10) \qquad P < P_R \rightarrow G^- = 0.$$

If the market price exceeds the release price, on the other hand, the government releases its entire corn inventory G,

$$(11) \qquad P > P_R \rightarrow G^- = G.$$

Alternative Deficiency Payment Programs

Under the current federal income support program, a participating corn producer receives a per-acre deficiency payment that is calculated by multiplying the national deficiency payment rate times the individual program yield. The deficiency payment rate is the difference, if positive, between the target price P^T and the greater of the market price P and the loan rate P^L. Denoting the program yield of participating corn producer i in region j by Y_{ij}^*, the per-acre payment received by the producer under the current deficiency payment program is given by

$$(12) \qquad D_{ij}^P = \max\{0, P^T - \max\{P, P^L\}\} \cdot Y_{ij}^*.$$

Under a regional target revenue program, a participating corn producer in region j would receive a basic per-acre deficiency payment equal to the difference, if positive, between the regional target revenue R_j^T and the participant regional average revenue, which equals the maximum of the market price and the loan rate times the regional average yield Y_j. In order to account for differences in productivity among corn producers, the basic payment is adjusted by a factor equal to the ratio of the individual's program yield and the regional average program yield Y_j^*. The per-acre deficiency payment received by participating producer i in region j under a regional target revenue program is, thus,

$$(13) \qquad D_{ij}^R = \max\{0, R_j^T - \max\{P, P^L\} \cdot Y_j\} \cdot \frac{Y_{ij}^*}{Y_j^*}.$$

A regional target revenue program will provide the same expected payment as the target price program, provided that the revenue target R_j^T is chosen so that

$$(14) \qquad \mathscr{E} \max\{0, P^T - \max\{P, P^L\}\} = \mathscr{E} \max\{0, R_j^T - \max\{P, P^L\} \cdot Y_j\} \cdot \frac{1}{Y_j^*},$$

where $\mathscr{E}$ denotes the expectation with respect to the joint distribution of price and yield. A unique revenue target satisfying this condition clearly exists since the expression on the right-hand side of (14) is zero if R_j^T is zero, is strictly and continuously increasing in R_j^T wherever the expectation is positive, and can be made arbitrarily large by raising R_j^T.

Although various regional configurations for a corn target revenue program are possible, only national, state, and county target revenue programs will be examined in this paper. Under a county target revenue program, Y_j and Y_j^* represent the average realized and program county yields, respectively; under a state target revenue

progam, they represent the average realized and program state yields, respectively; and under a national target revenue program, they represent the average realized and program national yields, respectively. Under any of the regional target revenue programs, any two corn producers having the same individual program yield and residing in the same region will, in any year, receive the same deficiency payment, regardless of any differences in their realized individual yields.

Empirical Model Parameterization

The regional simulation model of the U.S. corn market comprises the 1,142 largest corn-producing counties in the United States, which account for over 90% of all corn production nationally, and 137 multicounty regions that account for all the remaining U.S. corn production. The empirical market model was simulated, for the most part, under conditions prevailing during the 1989 marketing year. The national target price was set at $2.84 per bushel, the national loan rate at $1.65 per bushel, and the national release price at $2.84 per bushel, their 1989 values. Initial government corn inventories were set at 1.1 billion bushels, the combined level of Commodity Credit Corporation and Farmer-Owned Reserve holdings at the end of the 1988 marketing year. Because 1989 county-level corn acreage data were unavailable, program and nonprogram corn acreages were set at their 1984–88 average; total U.S. acreage and acreage for the top fifteen states ranked in order of descending program acreage are given in table 1.

Table 1. Number of Corn-Producing Counties and Corn Acreage by State

State	Number of Counties	Program Acres	Non-program Acres	Total Acres
		(million acres)		
Iowa	99	10.9	1.0	11.8
Illinois	100	8.3	2.0	10.3
Nebraska	82	6.2	0.7	6.8
Minnesota	70	5.0	0.6	5.7
Indiana	89	4.4	1.1	5.5
Ohio	74	2.7	0.8	3.5
South Dakota	46	2.6	0.2	2.8
Michigan	46	1.9	0.4	2.3
Wisconsin	56	1.9	1.0	2.9
Missouri	71	1.5	0.7	2.2
Texas	42	1.0	0.4	1.4
Kansas	52	1.0	0.1	1.2
North Carolina	48	0.8	0.5	1.3
Kentucky	50	0.7	0.6	1.4
North Dakota	12	0.5	0.0	0.5
Rest of U.S.[a]	342	3.2	4.0	7.2
U.S. Total	1,279	52.5	14.2	66.7

[a] Number reflects the aggregation of some smaller corn-producing counties into multicounty regions.

In order to preserve the observed covariation among the regional corn yields in the simulations, empirical yield distributions were employed. The empirical yield distributions were constructed by adjusting observed 1972–88 county-level corn yields for secular trends by state to reflect 1989 production levels. Table 2 gives the expectation and the standard deviaton of the trend-adjusted state corn yields, together with the average 1989 corn program yields by state. Table 2 also gives the state yield "beta," a normalized measure of the covariance between the state corn yield Y_j and the national corn yield Y:

$$(15) \qquad \beta_j = \frac{\text{Cov}\,(Y_j, Y)}{\text{Var}\,(Y)}.$$

Total demand for corn was formulated as the sum of domestic and export demand, both of which were specified in Cobb-Douglas form expressing quantity demanded in billions of bushels in terms of price in 1989 dollars per bushels. The constant term and elasticity for the domestic demand function were 6.615 and −0.3, respectively; the constant term and elasticity for the export demand function were 3.392 and −0.9, respectively.

Revenue targets for the hypothetical national, state, and county target revenue programs were set so that each participating corn producer's expected deficiency payment was the same under each of the target revenue programs as under the target price program. This was accomplished by solving (14) numerically for the revenue target level for each region and program. It was further assumed, as a first-order approximation, that corn producers maximize expected profits. The constancy of the expected deficiency payment thus implies that corn producer acreage supply decisions will not vary across the four programs. Table 3 gives the state and national revenue targets for corn; county-level revenue targets have been omitted for lack of space.

Regional Revenue and Government Cost Stabilization

Supplemental disaster assistance is provided in response to widespread regional crop failures,

Table 2. Program Yield, Expected Yield, Yield Standard Deviation, and Yield Beta for Corn, by State

State	Program Yield	Expected Yield	Standard Deviation of Yield	Beta
	(Bushels/Acre)			
Iowa	117	120	17.0	1.27
Illinois	117	117	19.2	1.44
Nebraska	109	130	11.3	0.68
Minnesota	103	114	17.3	1.19
Indiana	110	116	16.3	1.17
Ohio	110	119	14.1	0.86
South Dakota	65	78	13.5	0.93
Michigan	97	99	11.5	0.67
Wisconsin	105	109	14.4	0.88
Missouri	93	101	20.2	1.45
Kansas	109	131	12.4	0.71
Texas	94	93	11.5	0.34
North Carolina	78	76	11.9	0.22
Kentucky	95	91	15.1	0.90
North Dakota	64	80	12.2	0.65
Rest of U.S.	88	100	11.6	0.43
U.S. Average	105	112	12.6	1.00

rather than isolated individual crop failures. If a deficiency payment program is to eliminate the demand for supplemental disaster assistance, it must limit revenue shortfalls at the regional level. In this section, we examine how target price and target revenue deficiency payment programs stabilize corn revenues at the county level. We also compare government expenditure variability across programs.

Table 3 gives expected revenues for deficiency payment program participants and nonparticipants by state and nationally. Because the deficiency payment expected by any participating corn producer is, by design, the same under the three target revenue programs as under the target price program, the expected net revenue for any participating producer is the same under all four programs. Regional price discrepancies arising from basis differentials are ignored; therefore, regional differences in market revenues for nonparticipants are exclusively the result of variations in regional corn yields. Re-

Table 3. Mean Expected Revenue for Corn Deficiency Payment Program Participants and Nonparticipants, by State, and Mean-Preserving State and National Revenue Targets

State	Non-participants	Participants	Revenue Target
	($/Acre)		
Iowa	229.5	331.2	331.2
Illinois	223.7	325.4	325.4
Nebraska	253.3	348.1	347.5
Minnesota	218.5	308.0	308.0
Indiana	221.7	317.3	317.3
Ohio	228.9	324.5	324.5
South Dakota	148.0	204.5	204.5
Michigan	192.5	276.8	276.3
Wisconsin	209.6	300.8	300.8
Missouri	191.0	271.9	271.9
Kansas	253.7	348.5	347.9
Texas	181.7	263.4	261.6
North Carolina	147.6	215.5	214.4
Kentucky	175.2	257.8	257.8
North Dakota	154.8	210.4	209.5
Rest of U.S.	194.6	271.2	269.5
U.S. Average	217.3	309.1	306.8

gional differences in market revenues for program participants further reflect the differences among regional program yields and revenue targets. A comparison of participant and nonparticipant expected revenues indicates that, under 1989 conditions, the typical participating U.S. corn producer would expect to receive a deficiency payment of nearly $92 per planted acre.

As shown in table 4, expected government deficiency payments to corn producers under each of the four programs total $4.82 billion annually. Total government expenditures, however, are substantially more stable under the target revenue programs than under the target price program. The standard deviation of government deficiency payment outlays is $2.35 billion under the target price program but $0.98, $0.93, and $0.91 billion under the national, state, and county target revenue programs, respectively. A target revenue program thus reduces government expenditure variability by about 60% relative to a target price program.

Table 5 shows the average variability of county-level per-acre corn revenues for participants under the four alternative deficiency payment programs and also for nonparticipants. A semivariance statistic is used to measure downside revenue variability. Specifically, revenue variability is measured by the standard semideviation, which is defined for any n revenue observations $R_1, R_2, \ldots, R_n$ with mean $\bar{R}$ as

$$(16)\qquad s_R = \sqrt{\sum_{i=1}^{n} 2 \cdot (\max\{0, \bar{R} - R_i\})^2}.$$

The double counting of the negative revenue deviations assures that the semivariance measure is compatible with more conventional variability measures; specifically, if the distribution of the revenues is symmetric, the standard semideviation will equal the conventional standard deviation. The standard semideviation provides a measure of the downside revenue loss typically experienced by corn producers county-wide in below-normal years.

As seen in table 5, a target price deficiency payment program destabilizes county-level per-acre corn revenues, on average, in eleven of the top fifteen U.S. corn-producing states. For a typical U.S. corn-producing county, per-acre revenue variability is $29.60 per acre for nonparticipants, but $45.50 per acre for target price program participants. These findings support the view that the value of the current deficiency payment program to corn producers derives from the high level of income transfer it provides, not its ability to stabilize income.

A target price program destabilizes producer revenues by undermining the competitive market's natural revenue stabilization mechanism. In the absence of government price intervention, when aggregate yield falls, prices rise, and vice versa. This natural response of price to yield variations provides a moderating "natural hedge" against the revenue shortfalls that might otherwise result from yield shortfalls. A target price deficiency payment program stabilizes the effective price received by corn producers around the target price but removes the natural price hedge in the process (Grant, Miranda and Helmberger). Because the stabilizing effect of the natural hedge on regional revenues is strongest for regions whose yields are highly correlated with the national yield, it is precisely those regions that suffer the greatest revenue destabilization under a target price program. This assertion is confirmed by comparing the average county-level revenue variability to the state yield beta (table 2).

Target revenue programs do not destroy the natural hedge between price and yield and thus provide better overall revenue stability. Under a national target revenue program, most states exhibit significantly lower county-level revenue variability relative to a target price program. Only Nebraska, Kansas, Texas, and North Carolina fail to show a significant improvement under a national target revenue program. Notably, these are states in which the target price program is revenue stabilizing because of the low correlation between the state and national corn yields and the absence of an appreciable natural price hedge. For a representative U.S. county, corn

Table 4. Mean and Standard Deviation of Total Annual Government Deficiency Payments to Corn Producers Under Alternative Deficiency Payment Programs

	Target Price	National Target Revenue	State Target Revenue	County Target Revenue
	($ billion)			
Expectation	4.82	4.82	4.82	4.82
Standard deviation	2.36	0.98	0.93	0.91

Table 5. Standard Semi-Deviation of County-Level Per-Acre Corn Revenue Under Alternative Deficiency Payment Programs, Average by State

State	Nonparticipants	Target Price	National Target Revenue	State Target Revenue	County Target Revenue
			($/acre)		
Iowa	31.2	54.0	33.0	27.9	0.1
Illinois	27.2	61.0	32.0	21.8	0.0
Nebraska	33.0	27.1	26.5	19.9	1.7
Minnesota	27.1	47.4	28.3	18.0	0.1
Indiana	22.4	50.1	24.9	17.5	0.0
Ohio	31.2	42.7	25.5	18.2	0.1
South Dakota	21.5	32.4	22.9	15.0	0.5
Michigan	28.3	35.7	23.0	16.8	1.1
Wisconsin	27.1	45.4	25.7	17.0	1.0
Missouri	32.6	54.8	37.8	26.5	0.3
Kansas	39.8	33.0	33.4	27.4	2.6
Texas	37.3	31.2	30.7	23.4	4.1
North Carolina	34.4	30.8	30.7	18.0	2.2
Kentucky	28.7	49.9	32.9	18.3	0.2
North Dakota	24.0	26.8	21.9	12.8	1.7
Rest of U.S.	37.2	31.6	31.7	16.7	3.4
U.S. Average	29.6	45.5	29.3	21.0	0.7

revenue variability will be $29.30 per acre under a national target revenue program as compared to $45.50 per acre under a target price program, an improvement of 36%.

As shown in table 5, the amount of downside revenue protection afforded by a target revenue program substantially improves if the program is implemented on a state rather than national level. For the top fifteen corn-producing states, a state target revenue program stabilizes county-level revenues to a greater extent than either a target price or national target revenue program and in no case destabilizes revenues relative to nonparticipation. For a representative U.S. county, corn revenue variability will be $21.00 per acre under a state target revenue program, an improvement of 54% over a target price program.

The greatest stabilization of county-level revenues, however, is obtained through a county target revenue program. A county target revenue program will be more responsive to the effects of local crop failures than either state or national target revenue programs. Because of high levels of support implicit in the corn deficiency payment program in 1989, the equivalent county revenue targets are such that the probability of a county revenue exceeding its target will be negligible for the vast majority of U.S. corn-producing counties. In Iowa, Illinois, Minnesota, Indiana, and Ohio, states which account for over 60% of total U.S. corn production, a county target revenue program will reduce participant county-level revenue variability to less than 15¢ per acre on average. For a representative U.S. county, corn revenue variability will be less than 73¢ per acre, indicating a more than 98% improvement over the target price program.

Table 6 provides an indication of how the findings depend on the assumptions regarding the corn market model parameters. In this table, U.S. average county-level corn revenue variability under different deficiency payment programs are reported for the base case and for five scenarios. In the first four scenarios, the demand elasticities are varied over a wide range; in the remaining scenario, a reduction in the target price is considered. As seen in table 6, the findings regarding the superiority of the county target revenue program are robust with respect to demand elasticity specification. Under all four scenarios in which the elasticities are varied, county-level revenues are 98% more stable under a county target revenue program than under a target price program.

As seen in table 6, the stabilizing effects of a county target revenue program are still substantial, though less dramatic, if the target price is significantly reduced. Specifically, if the target price is lowered by 60¢ per bushel, county-level revenue variability will be $5.30 per acre under the county target price program offering the same level of support. This level of variability, how-

Table 6. Standard Semi-Deviation of County-Level Per-Acre Corn Revenue Under Alternative Deficiency Payment Programs and Alternative Corn Market Model Parameterizations, U.S. Average

Scenario	Nonparticipants	Target Price	National Target Revenue	State Target Revenue	County Target Revenue
	($/acre)				
Base case	29.6	45.5	29.3	21.0	0.7
Domestic elasticity = 0.1	30.4	45.4	29.1	20.9	0.2
Domestic elasticity = 1.0	27.7	42.9	27.9	20.1	0.1
Export elasticity = 0.1	31.0	45.6	29.4	21.1	0.9
Export elasticity = 2.0	27.4	44.5	28.6	20.5	0.5
Target price = $2.25	29.6	33.8	29.3	22.0	5.3

ever, still represents an 84% reduction relative to the target price program. When the target price is reduced, the corresponding revenue targets fall. Because the revenue targets are lower and thus less effective at truncating the revenue distribution, revenues become less stable under the county target revenue program. These results suggest that a county target revenue program may not eliminate the demand for supplemental disaster assistance entirely if the overall level of support provided by the program, and thus the revenue targets, are low.

Individual Revenue Stabilization

We now examine how target revenue deficiency payment programs stabilize revenues of individual corn producers relative to a target price program. We begin by constructing a model of how a representative corn producer's yield is distributed conditional on the surrounding county yield. We then link the individual yield model to the regional corn model developed above and simulate the combined model to estimate the revenue variability experienced by individual corn producers under alternative deficiency payment programs.

An individual corn producer's yield, say yield Y_{ij} of individual i in county j, is related to the county yield Y_j through the identity

$$(17) \qquad Y_{ij} = \bar{Y}_{ij} + \beta_{ij} \cdot (Y_j - \bar{Y}_j) + \tilde{\epsilon}_{ij},$$

where $\bar{Y}_{ij}$ is the producer's expected yield, $\bar{Y}_j$ is the expected county yield, and $\tilde{\epsilon}_{ij}$ is a zero-mean random variable that is uncorrelated with the county yield. Here,

$$(18) \qquad \beta_{ij} = \text{Cov}\,(Y_{ij}, Y_j)/\text{Var}(Y_j)$$

measures the sensitivity of the producer's yield to systemic factors that affect the county yield. The producer's beta coefficient can be equivalently and more conveniently written as the product

$$(19) \qquad \beta_{ij} = \rho_{ij} \cdot \frac{\sigma_{\tilde{Y}_{ij}}}{\sigma_{\tilde{Y}_j}}$$

of the correlation between the producer's yield and the county yield ρ_{ij} and the ratio of the standard deviations of the producer's yield $\sigma_{\tilde{Y}_{ij}}$ and the county yield $\sigma_{\tilde{Y}_j}$ (Miranda).

Equation (17) is an identity by construction and requires no special assumptions to hold. To construct a complete working model of individual corn yields, however, requires some distributional assumptions. First, the individual yield residual $\tilde{\epsilon}_{ij}$ is assumed conditionally independent of the county yield Y_j. This is a mild assumption given that the two random variables are uncorrelated by construction. Second, the residual yield term $\tilde{\epsilon}_{ij}$ is assumed normally distributed conditional on the county yield. This, too, places only mild restrictions on the shape of the producer's yield distribution since most individual yield variation is captured by the county-systemic terms $\beta_{ij} \cdot (Y_j - \bar{Y}_j)$, whose distribution is specified nonparametrically and empirically. Given these assumptions, an individual corn producer's yield distribution is completely determined by the expected yield, the yield variability, and the correlation between the yield and the county yield.

Table 7 shows individual per-acre revenue variability for representative corn producers under alternative deficiency payment programs. Nine representative producers, classified according to the variability of their individual yield and the correlation of their individual yield to their county yield, are considered. The figures reported in table 7 represent the acreage-weighted averages across all U.S. corn-producing counties of the representative individual revenue variabilities as measued by the standard semide-

Table 7. Standard Semi-Deviation of Per-Acre Revenue for Representative U.S. Corn Producers Classified According to the Correlation between Their Individual Yield and the County Yield and the Variability of Their Individual Yield Relative to the County Yield

Yield Correlation	Program	Relative Yield Variability[a] 120%	140%	160%
			($/acre)	
.5	Target price	46.9	54.9	62.9
	Target price & crop insurance	42.1	47.9	53.6
	National target revenue	41.6	48.2	55.1
	State target revenue	40.3	46.2	52.6
	County target revenue	38.7	43.9	49.8
.7	Target price	49.6	58.1	66.6
	Target price & crop insurance	46.0	53.0	60.0
	National target revenue	39.3	46.4	53.8
	State target revenue	35.6	41.8	48.6
	County target revenue	30.9	36.2	42.4
.9	Target price	53.0	62.1	71.3
	Target price & crop insurance	51.6	60.2	68.8
	National target revenue	37.6	45.4	53.6
	State target revenue	30.4	37.4	45.2
	County target revenue	19.9	26.2	33.7

[a] Standard deviation of the individual yield as a percentage of the standard deviation of the county yield.

viation. Each representative corn producer's expected yield and program yield are assumed to equal the county average.

In addition to the one target price and three target revenue schemes examined thus far, we also consider revenue variability under a target price program assuming that federal crop insurance is purchased by the producer. The producer is assumed to elect yield guarantee of 75% of normal yield and a price guarantee of 90% of expected price, the most common choices under the current crop insurance program. Thus, if the insured individual's corn yield falls below 75% of normal, the individual receives a per-acre indemnity payment equal to the yield shortfall times the price election. The insured producer's premium payment is assumed to be actuarially fair; that is, the premium equals the expected indemnity.

As seen in table 7, crop insurance provides only a modest improvement in the individual revenue risk protection offered by a target price program. This result is not particularly surprising in light of the significant limitation of coverage imposed by the 25% deductible. Suggestions to lower the deductible to improve individual coverage historically have been resisted because doing so would promote substantial moral hazard.

As seen in table 7, state and county target revenue programs consistently outperform the target price program, even when the latter is supplemented with crop insurance. Relative to a target price deficiency payment program with crop insurance, the improvement in individual revenue risk reduction afforded by a county target revenue program ranges from 7% (from $53.60 to $49.80 per acre) for the low correlation, high variance producer to 61% (from $51.60 to $19.90 per acre) for the high correlation, low variance producer. Although not reported, these patterns persist on a state-by-state basis.

A county target revenue program does not base deficiency payments on individual revenue losses and thus is not, strictly speaking, a revenue insurance program. A target revenue program is more comparable to a free put option in which the county revenue target plays the role of the strike price and the county revenue plays the role of the price of the underlying security (Gardner, Marcus and Modest). Because the county target revenue program offers a hedge rather than pure insurance against individual revenue risk, its effectiveness at reducing individual revenue risk depends mainly on the correlation between the producer's individual revenue and the county revenue.[4] As seen in table 7, the improvement afforded by a county target revenue program is

[4] By addressing price and yield risk simultaneously, the target revenue program may be viewed as a generalization of the area-yield crop insurance scheme, which has recently received renewed attention (Halcrow, Miranda).

substantial if the producer's yield is highly correlated with the county yield but is more modest for lower degrees of correlation.

The concern over individual income risk coverage raises the question whether an individualized target revenue program, in which payments are based on individual revenue shortfalls, might not be more desirable than a county target revenue program. An individualized target revenue program providing the high level of income transfer associated with the current deficiency payment program, however, would give rise to severe moral hazard and thus would not be sustainable. Moral hazard would not only lead to serious resource misallocation, it would also raise overall government direct expenditures on the program. In order to combat moral hazard and to recover the increased costs, the government would ultimately have to lower substantially the revenue targets under an individualized program, thereby reducing the level of income transfer and the revenue risk protection provided by the program. A county target revenue program, in contrast, would not be subject to moral hazard, regardless of the overall level of income transfer provided by the program.

Conclusions

This paper has examined a modification of the current deficiency payment program that would address a pervasive weakness of current federal income support programs: the failure to provide producers with adequate protection in the event of a widespread crop failure. Under the modified deficiency payment program, payments would be based on shortfalls in regional per-acre revenues relative to a specified revenue target rather than on shortfalls in price. Because yield and price are negatively correlated, deficiency payments would be higher under a target revenue program than under a target price program when yields are low, thereby providing improved income protection in the event of a crop failure.

A regional model of the U.S. corn market was used to evaluate national, state, and county target revenue deficiency payment programs. Our analysis indicates that for the same cost as the current target price program, a county target revenue program for corn would dramatically reduce county-level revenue variability and would stabilize government deficiency payment program outlays. A county target revenue program would provide better individual income risk protection to corn producers than the current target price program, even when the latter is supplemented by individualized crop insurance, and would not be subject to the moral hazard problems that have historically undermined the actuarial performance of the federal crop insurance program. More important, however, a county target revenue program providing the same overall level of support as is currently enjoyed by corn producers would place a sufficiently high floor on county-level corn revenues that the demand for supplemental disaster assistance would be significantly reduced if not eliminated.

Sensitivity analysis suggests that our findings are robust to parametric specification and thus should hold for comparable program crops. Care should be taken, however, not to generalize the findings to crops currently not receiving significant income support. A target revenue program for non-program crops would presumably require compensating premium payments from producers to operate on an actuarially sound basis. If premiums are to remain moderate, the associated revenue targets would be low relative to normal revenue expectations and might not provide the high floors on regional revenues that would obtain for program crops. Analysis of target revenue programs for nonprogram crops, as well as for program crops other than corn, must be conducted before generalizations about the cost effectiveness of target revenue programs can safely be made. Our findings suggest that such studies may well be worth while, particularly in light of the high cost of recurring disaster assistance legislation.

[Received July 1990; final revision received January 1991.]

References

Arzac, Enrique R. "Income Insurance with Uncertain Output." *Int. Econ. Rev.* 30(1989):561–69.

Chambers, Robert G. "Insurability and Moral Hazard in Agricultural Insurance Markets." *Amer. J. Agr. Econ.* 71(1989):604–16.

Evans, R.S. "Cotton Farm Program Issues." *Proceedings of the Beltwide Cotton Production Research Conference*, pp. 279–82. Memphis TN: National Cotton Council of America, 1984.

Gardner, Bruce L. "Commodity Options for Agriculture." *Amer. J. Agr. Econ.* 59(1977):978–92.

Glauber, J. W., J. L. Harwood, and M. J. Miranda. *Federal Crop Insurance and the 1990 Farm Bill: An Assessment of Program Options.* Washington DC: U.S.

Department of Agriculture, Econ. Res. Serv. Staff Rep. No. AGES89-45, Sep. 1989.

Grant, D. "Joint Output and Price Uncertainty." *Amer. J. Agr. Econ.* 67(1985):630–35.

Halcrow, Harold G. "Actuarial Structures for Crop Insurance." *J. Farm Econ.* 21(1949):418–43.

Marcus, A. J., and D. M. Modest. "The Valuation of a Random Number of Put Options: An Application to Agricultural Price Supports." *J. Finan. and Quant. Anal.* 21(1986):73–86.

Miranda, M. J. "Area-Yield Crop Insurance Reconsidered." *Amer. J. Agr. Econ.* 73(1991): 233–42.

Miranda, M. J., and P. G. Helmberger. "The Effects of Price Band Buffer Stock Programs." *Amer. Econ. Rev.* 78(1988):46–58.

Nelson, Carl H., and Edna T. Loehman. "Further Toward a Theory of Agricultural Insurance." *Amer. J. Agr. Econ.* 69(1987):523–31.

Offut, Susan E., and David A. Lins. "Income Insurance for U.S. Commodity Producers: Program Issues and Design Alternatives." *N. Cent. J. Agr. Econ.* 7(1985):61–69.

Skees, Jerry R., and Michael R. Reed. "Rate-Making and Farm-Level Crop Insurance: Implications for Adverse Selection." *Amer. J. Agr. Econ.* 68(1986):653–59.

U.S. Department of Agriculture. *Farm Income Protection Insurance: A Report for the United States Congress.* Farm Income Protection Insurance Task Force, Washington DC, June 1983.

——. *1990 Farm Bill: Proposal of the Administration.* Office of Publishing and Visual Communication, Washington DC, Feb. 1990.

U.S. Congressional Budget Office. *Farm Revenue Insurance: An Alternative Risk-Management Option for Crop Farmers.* Washington DC, Aug. 1983.

U.S. General Accounting Office. *Disaster Assistance: Crop Insurance Can Provide Assistance More Effectively Than Other Programs.* Report to the Chairman, Committee on Agriculture, U.S. House of Representatives, GAO/RCED-89-211. Washington DC, Sep. 1989.

Explaining Price Policy Bias in Agriculture: The Calculus of Support-Maximizing Politicians

Harry de Gorter and Yacov Tsur

A model is developed to explain observed patterns of policy intervention in agriculture. We analyze the interaction between political support-seeking politicians and support-supplying citizens. Society consists of a rural and urban group. We determine the effects on transfers of relative group size, disparities in income endowments between groups, and the deadweight loss of redistribution. The framework advanced is an alternative to that of the interest group model and is used to explain, for example, why the export sectors in developing countries are taxed more and why the United Kingdom is less adamant for higher price supports than Germany.

Key words: group size, income endowments, price bias, redistributed income.

> . . . a challenging puzzle . . . why is there such a strong perverse relationship between the proportion of the population who are farm people and their political influence in shaping food and agricultural policies? A corollary . . . why do governments in many low income countries persistently undervalue agricultural products? (T. W. Schultz)

The most commonly observed pattern of government intervention in agriculture across countries and over time is that protection afforded farmers is positively correlated with average per capita incomes (Bale and Lutz; Binswanger and Scandizzo; Anderson and Hayami; Krueger, Schiff, and Valdes). Anderson and Tyers, for example, conclude that society has an income-elastic demand for assisting farmers. Indeed, developing countries with relatively low per capita national incomes tend to tax agriculture. Although alternative explanations for this pattern of intervention have been advanced including social welfare maximization (Johnston and Mellor) and "class" theories of special interests using the state for their own benefit (de Janvry), the most common theory focuses on the behavior of interest groups (Olson 1985, 1986; Becker; Gardner; Balisacan and Roumasset). This theory argues that fewer firms promote the political power of an industry by reducing costs of organizing, preventing free-riding, and mitigating opposition. It is assumed that politicians are passive and voters are rationally ignorant.

The purpose of this paper is to present an alternative model that explains agricultural protection as the outcome of the interaction between self-interested politicians and citizens. In this approach, politicians compete for political support defined in terms of votes, popularity ratings in polls, and other measures that reflect the intensity of preferences by citizens for the government. The manner in which policy interventions affect political opinions of individuals in society is integrated with the decisions by politicians, whereby price levels set by the government depend on political support from citizens and vice versa.

The political process consists of politicians on the one hand and voters (or citizens) on the other. Citizens are separated into two groups: land owners and labor owners.[1] The manner in which

Harry de Gorter is an assistant professor, Department of Agricultural Economics, Cornell University; Yacov Tsur is an assistant professor, Department of Agricultural and Applied Economics, University of Minnesota.

The authors thank Bill Foster, Masayoshi Honma, Steven Kyle, David Lee, Willis Peterson, Johan Swinnen, and two anonymous *Journal* referees for valuable comments.

[1] In industrial democracies, the agricultural sector consists mainly of family owned farms with some leasing of farmland. Thus, land owners comprise the entire agricultural sector. In developing countries, the agricultural sector consists also of landless workers; they are included in the urban group in this paper. Landless workers are viewed as "labor owners" and are assumed to be free to sell their labor services in the urban sector. Land, on the other hand, is immobile and, as such, absorbs the residual between revenues and production costs, i.e., the production rents. Any change in prices would be reflected in land rents, thereby affecting land values. Thus, land owners are determined to be the main gainers or losers of agricultural policies.

members of each group form political opinions and, accordingly, allocate their political support is represented by a specific support function. Politicians or the government set various policies, such as price supports, subsidies, and tariffs, which translate into the transfer of wealth between groups. In so doing, we assume that politicians seek the goal of maximizing political support from members of each group. Thus, political support forthcoming from individual members plays an important role in the policy choice mechanism, in addition to other factors, such as relative group size, income endowments and the deadweight loss of redistribution. The effect of these factors will be evaluated and compared to the observed patterns of agricultural policy intervention.

The following section presents a politician-voter interaction model and derives several propositions on the above-mentioned factors. The relationship between our model of self-interested support-maximizing politicians and a benevolent government maximizing a utilitarian social welfare function is also discussed. Empirical evidence of the hypotheses is then presented. A final section offers some conclusions.

A Theoretical Model

Consider an economy with two homogenous groups: urban (labor owners) group of size n_u and a rural (land owners) group of size n_r, with $n = n_u + n_r$ the total number of members. Let T denote the total income transfer from the urban to the rural group (a negative T denotes an income transfer from rural to urban) and let $t = T/n_u$ be the per capita urban tax. The per capita subsidy to the rural sector is thus $t_r = T/n_r = tR$, where $R = n_u/n_r$ is the population ratio. Let $Y_u^o(t)$ and $Y_r^o(t_r)$ denote the urban and rural per capita endowment income net of transfer payments t, so that

$$(1) \qquad Y_u(t) = Y_u^o(t) - t \text{ and}$$

$$(2) \qquad Y_r(t_r) = Y_r^o(t_r) + t_r$$

are total realized per capita urban and rural incomes, respectively.

The transfer T distorts individual choices which results in the (per capita) deadweight losses $Y_u^o(0) - Y_u^o(t)$ and $Y_r^o(0) - Y_r^o(t_r)$. If the policy is implemented by commodity taxation, then the deadweight cost can be represented by the welfare triangles corresponding to the individual demands. If income taxes are used, the deadweight costs result from the distortions in labor-leisure, investment, and other decisions by economic agents. We explicitly assume that both $Y_u^o(t)$ and $Y_r^o(t_r)$ are increasing for negative t and decreasing for positive t, each attaining a unique maximum at $t = 0$.

The derivatives $Y_u^{o'}(t)$ and $Y_r^{o'}(t_r)$ are the marginal deadweight loss functions (the prime notation indicates a derivative with respect to the explicit argument; thus $Y_u^{o'}(t)$ and $Y_r^{o'}(t_r)$ are derivatives with respect to t and $t_r = Rt$, respectively). The deadweight loss functions depend on the marginal excess burden of taxation and subsidization. A discussion on the implications is delayed.

The notion of political support is interpreted as the probability that a member expresses support for the government through votes, popularity polls, and the like (Downs, Peltzman, de Gorter). Two motives are assumed to determine the formation of political opinion by members: the relative income motive and the redistributed income motive. The relative income motive draws upon the literature of relative deprivation, which maintains that a member feels deprived with respect to those with a higher income and feels satisfied with respect to those with a lower income (Runciman, p. 10; Sen; Yitzhaki). These feelings of deprivation and satisfaction are incorporated into a member's political support functions.

Formally, let $h_{ij}(t) = y_i(t) - y_j(t)$ be the income gap between members i and j, with $y_i(t)$ indicating the income of member i. Let $h_i(t)$ be the aggregate income gap of member i. Then the relative income motive of member i is represented by a monotonic function of $h_i(t)$, to be denoted by $G(\cdot)$. Thus, an increase in the aggregate income gap (which may be caused by an increase in the number of members with lower income or a decrease in the number of members with higher income or changes in the individual income gaps) causes an increase in the intensity of the political support forthcoming from member i. In the present case, with two homogenous groups, the aggregate income gap of a rural member is $h(t) \cdot n_u$ and that of urban members is $-h(t) \cdot n_r$, where $h(t) = Y_r(t) - Y_u(t)$ is the income gap between a rural and an urban member. We assume that G vanishes over the interval $[-\infty, h]$ and increases at a diminishing rate over $(h, \infty]$. The vanishing part implies that no political support is forthcoming (resulting from the relative income motive) from a member whose aggregate income gap falls below some critical level h.

The redistributed income motive reflects the hypothesis that members prefer policies which transfer more wealth to them, and they translate these preferences into political support. We represent this motive by $F(y_i(t) - y_i(0))$, with $F(\cdot)$ an increasing and strictly concave function. This specification allows for the effect of intervention on political support and is similar to the standard specification in political economy models (see Brock and Magee; Peltzman; Magee, Brock, and Young). The urban and rural political support functions S^u and S^r are

(3) $$S^u(t) = W_1G(-h(t)\cdot n_r) + W_2F(Y_u(t) - Y_u(o)) \text{ and}$$

(4) $$S^r(t) = W_1G(h(t)\cdot n_u) + W_2F(Y_r(t) - Y_r(o)),$$

where W_1 and W_2 are nonnegative scalars summing to unity which represent the importance of the relative income motive and the redistributed income motive. Specifications (3) and (4) incorporate two main simplifying restrictions: (*a*) both S^u and S^r are additively separable in relative and redistributed income; (*b*) the effect of these factors is identical for all members (i.e., the same G and F functions and the same weights, W_1 and W_2, appear in S^u and in S^r).

The marginal deadweight losses $Y_r^{o'}(t_r)$ and $Y_u^{o'}(t)$ satisfy

(5) $$Y_r^{o'}(t_r) + 1 > 0 \text{ and } 1 - Y_u^{o'}(t) > 0.$$

Suppose $t > 0$, then both $Y_r^{o'}$ and $Y_u^{o'}$ are negative, but $Y_r^{o'}$ must exceed minus unity since otherwise a rural member would become worse off by receiving a larger subsidy. Similarly, when $t < 0$, both $Y_r^{o'}$ and $Y_u^{o'}$ are positive but $Y_u^{o'}$ must be less than unity since otherwise the urban member would benefit by receiving a smaller (positive) transfer. From (5) it follows directly that

(6) $$h'(t) = [Y_r^{o'}(t_r) + 1]R - Y_u^{o'}(t) + 1 > 0.$$

The government chooses t in order to maximize total political support:

(7) $$S(t) = n_u S^u(t) + n_r S^r(t).$$

The first-order condition requires that the optimal per capita transfer t^* satisfies

(8) $$W_1h'(t^*)n_un_r[G'(h(t^*)\cdot n_u) - G'(-h(t^*)\cdot n_r)] + W_2R[F'(g_u(t^*))Y_u'(t^*) + F'(g_r(t_r^*))Y_r'(t_r^*)] = 0,$$

where $g_j = Y_j(t) - Y_j(o)$, $j = u, r$ and it is recalled that $Y_r'(t_r) = \partial Y_r/\partial t_r$.

The transfer level which yields egalitarian income distribution is defined by t^e. That is, t^e satisfies

(9) $$h(t^e) = 0.$$

From (6), the unique level t^e is positive, zero, or negative whenever $h(0)$ is negative, zero, or positive, respectively.

The next stage is to analyze the effects on income transfers of the endowment income disparity, $h(0)$, the population ratio, R, and the magnitudes of the marginal deadweight losses, $Y_r^{o'}$ and $Y_u^{o'}$. We begin with the extreme cases in which either the relative income motive ($W_1 = 1$ and $W_2 = 0$) or the redistributed income motive ($W_1 = 0$ and $W_2 = 1$) prevail, followed by the more general case in which both W_1 and W_2 are positive.

The Relative Income Effect ($W_1 = 1$; $W_2 = 0$)

In this scenario, individuals deciding on their political support are concerned only with their income relative to that of the other members. Condition (8) specializes to

(10) $$G'(h(t^*)\cdot n_u) = G'(-h(t^*)\cdot n_r),$$

which, together with the strict concavity of $G(\cdot)$, imply:

PROPOSITION 1. *If members are concerned only with relative income, then* $t^* = t^e$.

Figures 1 and 2 provide graphical explanations. Figure 1 considers the case $h(0) < 0$. The curve labeled $h_1(t)$ corresponds to the case $R = 1$; the $h_2(t)$ and $h_3(t)$ curves correspond to $R > 1$ and $R < 1$, respectively. The corresponding equity transfers are t_1^e, t_2^e, and t_3^e. The equity tax t^e always moves toward zero as R increases, i.e., t^e decreases or increases with R as $h(0) < 0$ or $h(0) > 0$, respectively.

With $h(0) < 0$, so that $t^e > 0$, an increase in R implies that there are more members in the urban sector relative to the rural sector, and a

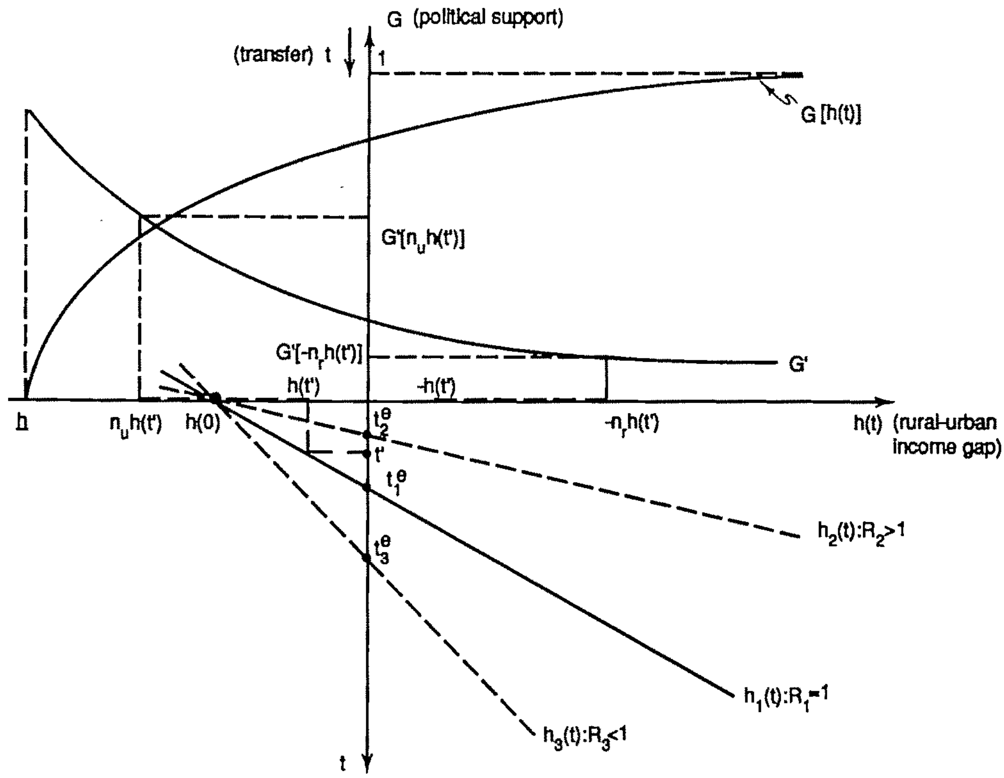


Figure 1. The case where the initial income gap, $h(0)$, is negative. R_1, R_2 and R_3 represent the cases where the urban-rural population ratio is equal to, greater than, and less than one, respectively; n_r, n_u represent rural, urban population, respectively; t^e is the transfer which equilibrates rural and urban incomes

smaller per capita urban tax is capable of generating the rural subsidy required to maintain equity. The effect of R on the per capita rural subsidy $t_r^* = Rt^* = Rt^e$ is given by $\partial t_r^*/\partial R = t^e + R(\partial t^e/\partial R)$; t^e and $\partial t^e/\partial R$ are always of opposite signs (t^e increases with R when t^e is negative and decreases with R when t^e is positive). Nevertheless, it is not hard to show the following:

PROPOSITION 2. *If $h(0)$ is negative (resp. positive, zero) then t^* ($= t^e$) decreases (resp. increases, does not change) and t_r^* ($= Rt^*$) increases (resp. decreases, does not change) with R.*

Proof: The effect of R on t^e is shown by the graphical explanation. To show the effect of R on $t_r^* = Rt^e$, consider first the case $h(0) < 0$. Suppose R increases from R_1 to R_2 ($R_1 < R_2$). Then we know that t^e decreases, say from t_1^e to t_2^e, implying—using properties (5)—that the income of urban members rises. Thus $Y_u^o(t_1^e) < Y_u^o(t_2^e)$. Because the income of a rural member must equal that of the urban member, the per capita rural income must increase too. Using property (5) again, this can occur only if t_r^* increases. The case $h(0) > 0$ is proven in a similar manner and when $h(0) = 0$, $t^e = 0$, and $t_r^* = 0$ disregarding the level of R.

The empirical implications of proposition 2 are important. In industrial countries, where R increases as the number of farmers relative to the urban population is declining and where the endowment incomes usually are in favor of the urban sector, the rural per capita subsidy is increasing while the per capita tax on the urban sector continuously declines. Hence, in this situation, the model predicts that countries with relatively fewer farmers will have rural subsidies because it is in the interest of support-maximizing politicians to do so even though there are relatively fewer farmers to obtain votes from. This result also arises from the interest group

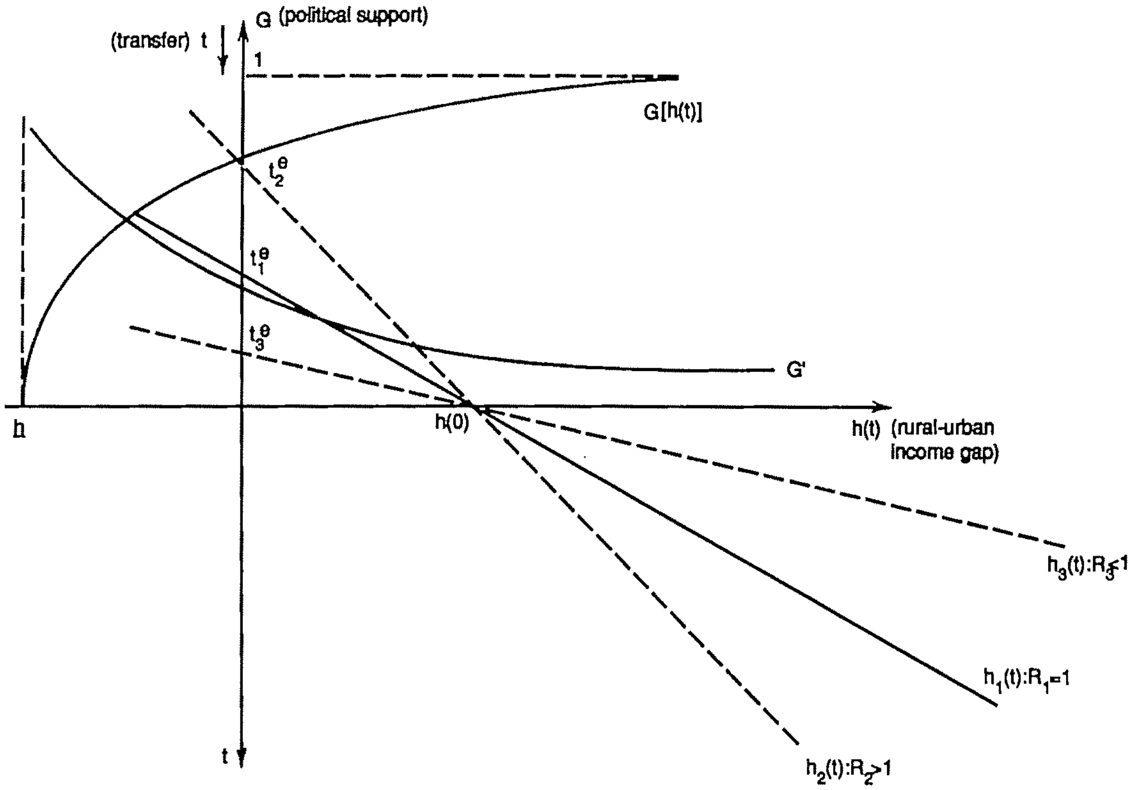


Figure 2. The case where the initial income gap, $h(0)$, is positive

model, but for different reasons. On the other hand, a developing country can have $h(0) > 0$, $R < 1$, and the rural sector be taxed. Thus, unlike the interest group model, our model does not require that the smaller group is always more successful in receiving subsidies. Unlike Downs and unlike Magee, Brock, and Young, our model does not have to assume rational ignorant voters in order for small groups to be subsidized.

Variations in endowment incomes because changes in technology or input costs (in either the agricultural or industrial sector) shift $h(0)$. For example, if the productivity in the industrial (urban) sector improves relative to the agricultural (rural) sector, then $Y_u(0)$ increases relative to $Y_r(0)$. This results in a leftward shift of the $h(t)$ function and an increase in the optimal urban tax $t^* = t^e$ and in rural subsidy t_r^*. Conversely, technological change that raises the relative productivity and endowment incomes of the rural sector will shift the function $h(t)$ to the right (in fig. 1) so that t^e decreases. The impact of endowment incomes is summarized in the following proposition, which can be verified using figures 1 and 2.

PROPOSITION 3. *The optimal per capita tax t^* ($= t^e$) decreases with $h(0)$.*

Propositions 2 and 3 can be used to explain why developing countries with the food problem tax farmers and industrial countries with the farm problem tend to subsidize farmers. Low income and price elasticities of demand for food in rich countries coupled with elastic supply elasticities and technological advances result in the farm problem of persistent rural-urban income disparities. In developing countries, excess food demand in the face of inelastic supply results in the food problem if governments fail to prevent sharp price increases to the poor. In each case, relative incomes affect the government's decision.

Government research expenditures, particularly in North America and Australia, improved agricultural productivity relative to manufacturing. Proposition 3 may partially explain Anderson and Tyers' observation that protection to farmers is relatively lower in these countries. The insistence by Germany (GER) for higher cereal support prices while the United Kingdom (UK)

is most strongly opposed can also be explained partially by the relative difference in endowment incomes between the rural and urban sectors in these countries. GER has many more cereal farms which are smaller in size and relatively more inefficient than those in the UK. From a strict interest group point of view, one would expect the UK to favor higher cereal prices. However, the increases in productivity in the industrial sector of GER have exceeded that of the UK in past decades, while the reverse is true in agriculture between the two countries. Hence, the relative propensity of political preferences in price policy in Europe can be explained in part by the divergence in relative endowment incomes between agriculture and manufacturing across countries.

While $h(0)$ is the intercept of the $h(t)$ function, the location and shape of the $h(t)$ depend also on its slope. This slope depends on R and on the marginal deadweight losses $Y_r^{o'}$ and $Y_u^{o'}$. The effect of R was summarized in proposition (2). We concentrate now on how the deadweight loss depends on factors such as the elasticity of supply and demand. To clarify the relationship between elasticities and the deadweight loss of a transfer, consider a production subsidy. Deadweight losses are incurred because farmers must produce more to get the subsidy (e.g., a target price scheme) or idle resources (e.g., if subsidies are based on an acreage diversion scheme as in the U.S.). Hence, a more elastic supply schedule with a subsidy *ceteris paribus*, yields in a higher deadweight loss. Furthermore, the net trade position for a country can significantly affect transfer efficiency. A large country importer can improve its terms of trade while an exporter does the opposite, thereby exacerbating the cost of transfers.

Formally, suppose the government changes the instruments it uses to tax and subsidize such that the urban sector is unaffected but the distortionary effects on the rural sector are more severe, i.e., $|Y_r^{o'}|$ increases for all $t \neq 0$. This has the effect of reducing rural income for a given level of transfer and causes $h(t)$ to turn clockwise (counter clockwise) about the point $h(0)$ when t is positive (negative). It can be verified using figures 1 and 2 that the result is an increase in the equity transfer t^e if $h(0)$ is negative and a decrease in t^e if $h(0)$ is positive. A *ceteris paribus* increase in $|Y_u^{o'}|$, for all $t \neq 0$ will have an opposite effect.

These results have important implications for observed patterns of government intervention in agricultural markets. Commodity sectors with more elastic supply functions tend to make producers in the rural sector more vulnerable to distortionary forces. Hence, one would expect higher producer subsidies (or lower producer taxes) in such cases. On the other hand, inelastic demand is associated with a lower deadweight loss for a given transfer. Thus, one would expect higher transfers in those sectors. These results are in contrast to that of Becker, who has transfers higher in sectors with a more inelastic demand and supply. U.S. Department of Agriculture (USDA) calculations indicate that inelastic demand commodities like fluid milk and wheat have higher producer subsidy equivalents world-wide than more elastic commodities like meat and feed grains. Furthermore, the efficiency of transfers is higher for importers than for exporters. It is generally recognized that importers protect agriculture more than exporters in industrial countries because the latter's terms of trade decline (improve) with the subsidization (taxation) of the rural sector (and vice versa for importers). This may partially explain Anderson and Tyers' observation that North America and Australia subsidize agriculture less because they are predominantly exporters and hence limit subsidies. The U.S. dairy and sugar sectors as net importers have higher rates of protection than export sectors (USDA).

The Pure Redistributed Incomes Effect ($W_1 = 0$; $W_2 = 1$)

In this scenario, individuals are concerned only with the effect of government policies on their own income. The condition (8) becomes

$$(11) \quad F'(g_r(t^*))\,(Y_r^{o'}(t_r^*) + 1) = F'(g_u(t^*))\,(1 - Y_u^{o'}(t^*)),$$

from which the following result follows.

PROPOSITION 4. *If a member's political support depends only on the change in income resulting from redistribution, then the optimal transfer is zero.*

Proof: From $Y_r^{o'}(0) = Y_u^{o'}(0) = g_r(0) = g_u(0) = 0$, it follows that $t^* = 0$ satisfies (11). Furthermore, $t^* = 0$ is the unique solution to (11), for suppose $t^* > 0$. Then, compared to the case $t^* = 0$, the left-hand side of (11) decreases because (*a*) g_r increases (becomes positive) which, by virtue of the strict concavity of F, causes $F'(g_r)$ to decrease, and (*b*) $Y_r^{o'}$ becomes negative so that $Y_r^{o'} + 1$ decreases. Likewise, both g_u and

$Y_u^{o'}$ become negative, which causes the right-hand side of (11) to increase. Thus $t^* > 0$ cannot be a solution. In a similar manner, a negative transfer is ruled out, leaving $t^* = 0$ as the unique solution.

Proposition (4) implies that a support-maximizing government will not redistribute income if redistributed income is the only factor affecting individuals behavior in supporting the government. This result holds regardless of the relative group size, the extent of income inequality between the groups, the initial level of income and of the marginal deadweight loss of redistribution. Proposition (4) also holds for the standard specification in the literature of support being a function of t instead of $(y_i(t) - y_i(0))$.[2] This result represents the opposite extreme to the case when $W_2 = 0$ and may serve to explain situations in which politicians are reluctant to intervene in agricultural markets.

The Mixed Case ($W_1 > 0$, $W_2 > 0$)

If both relative and redistributed incomes affect political support, then the tendency for governments to reduce the disparity in income distribution is partially mitigated by the effect of redistributed income on the level of political support. Hence, redistributed income considerations dampen the government's propensity to redistribute income away from the relatively advantaged group. The extent to which this occurs depends critically on the relative values of weights W_1 and W_2.

Self-Interest Politics and Social Welfare

Our model maintains that the government pursues the self-interest goal of maximizing its political support from citizens. Whether this is consistent with a benevolent goal of maximizing social welfare depends on (*a*) the determinants of the political support of individuals, and (*b*) the deadweight cost of redistribution.

If a voter's support was determined solely by his or her level of income (or utility), then maximizing total political support would be equivalent to a benign government-maximizing total income (or the sum of utilities). An example of the latter specification is given in Staiger and Tabellini. In this paper, however, we distinguish between the income (or utility) level associated with a certain policy and the support this policy receives. A member's support of a particular policy depends on the changes in the member's own income and in the income of other members, rather than the income levels themselves. A policy that equilibrates incomes between two individuals does not imply that they both equally support the policy, even though their post-policy incomes are identical. Rather, it is likely that the gainer will support the policy more than the loser.

However, costless transfers allow a government to redistribute so as to make everybody better-off and at the same time maximize political support. A public project that increases the income of one individual only allows the government to redistribute income so as to make everyone better off (relative to the pre-project situation) without losing political support from other individuals. Thus, if distortion-free transfers were possible, it is plausible that the government would choose the policy that maximizes the total income of members and then redistributes income so as to maximize support.

Distortion-free transfers, however, rarely exist in reality and, hence, are not evaluated in this paper. Thus, the chosen policies will not, in general, maximize total income. However, the political system considered here, which consists of support-seeking politicians, generates outcomes which are not necessarily inconsistent with that of a socially concerned system. For example, if $W_2 = 0$, then (compare proposition 1) the optimal redistribution of a support-maximizing government is the egalitarian one, which is consistent with the Rawlsian objective of maximizing the welfare of the worst-off individual. The entire issue of the relation between policies determined by self-interested politicians versus those determined by socially concerned politicians has recently become the subject of a growing literature (see the excellent survey by Baldwin).

Some Empirical Evidence

The above results suggest that a country that subsidizes (taxes) farmers is likely to have lower (higher) per capita endowment incomes in the rural sector than in the urban sector. This hypothesis is consistent with the observations by Anderson and Hayami that countries which sub-

[2] It should not be surprising that these models focus on lobbying activity in explaining government intervention. For example, see Peltzman; and Magee, Brock, and Young.

sidize farmers have high productivity rates and wages in the manufacturing sector (where one can hypothesize that rural endowment incomes are relatively lower), while the opposite is the case in developing countries. Relative prepolicy incomes in agriculture decline in the process of economic development. This may explain the observations by Anderson and Hayami that Southeast Asia and Europe shifted over time from taxing agriculture to subsidizing it and that agricultural protection has increased in industrial countries in the past several decades, while that for manufacturing has declined. Furthermore, Honma and Hayami find a statistical correlation between agricultural protection and both its comparative advantage and international terms of trade relative to the manufacturing sector. Hence, agriculture may have a comparative advantage in many developing countries so that endowment incomes would be higher, resulting in the taxation of the rural sector.

Krueger, Schiff, and Valdes determine the direct (sectoral) and indirect (macro) policy impacts on incentives in agriculture in eighteen developing countries. Farmers are taxed through import-substitution policies in the industrial sector, overvalued exchange rates via exchange-control regimes and import licensing, and suppressed farm prices via government procurement policies (especially marketing boards), export taxes, or quotas. Some of these taxes have been offset by subsidies to inputs, irrigation, and the like. Direct protection was found to be negative for exportables (typically nonfood crops) but positive (with exceptions) for importables (often food staples). Total protection average -7% for importables and -35% to -40% for exportables. The differential treatment against the export crop sectors in developing countries may occur because these sectors have a comparative advantage over import-competing food crop sectors. Hence, the latter sectors are taxed less and are in some cases even subsidized, although farmers in the export sector in developing countries are typically fewer and more able to organize as a pressure group.

The observation by Anderson and Tyers that Australia and North America, although highly industrialized economies, tend to protect farmers less may in part be explained by the fact that relative endowment incomes in agriculture may not be so low as in other countries because of agroclimatic conditions and the advancements in technology resulting from publicly funded research. Again, this finding is consistent with the results of our model.

European agricultural politics have reflected on increasing polarization between the UK and GER on matters relating to support prices of the Common Agricultural Policy (CAP). The UK has argued for lower price supports, while GER has supported higher prices. This disagreement occurs even though the total costs of the cereals regime is higher for GER because (*a*) GER's taxpayer contributions are higher because the value-added tax is based on the level of GNP, and the UK is one of the lower income members; and (*b*) UK's consumer costs are lower because they are a substantial net exporter of cereals (unlike GER). Hence, GER contributes to invisible transfers from consumers in GER to producers elsewhere in the EC resulting from intra-EC trade at supported prices. In addition, GER contributes more to import levy income resulting from off-shore trade because GER is a significantly larger net importer. Furthermore, the benefits of the cereal regime are greater for the UK because of larger production. Not only is the absolute level of farm benefits higher in the UK, but so, too, are the per capita benefits because the number of cereal farms is much higher in GER. In 1986, there were 50,000 general cropping farms in GER, with the UK having only 20,000 farms. Hence, it would appear puzzling why the UK is so adamant for lower prices and why GER argues for the opposite.

This irony is further complicated by the fact that not only are farms fewer in number in the UK, but they also are larger, geographically more concentrated, and more variable in size distribution, leading the Olson/Becker interest group models to predict that the price preferences of the UK and GER would be reversed.

The model developed in this paper emphasizes the importance of the relative rural-urban endowment income differential in explaining the UK and GER relative price preferences. The UK has few, large, and cost-efficient farms; while in GER farms are many, small, and high cost. On the other hand, the industrial sector in GER is richer than that of the UK. The prepolicy income gap between the rural and urban sectors is therefore higher in GER. It is possible that this prepolicy disparity in relative incomes is a fundamental force in the current and historical political economy of agricultural policy in these countries.

The prepolicy income disparity appears also to be a fundamental force in the political economy of agricultural protection in Japan. In describing policy developments during the past 100 years, Hayami emphasizes the importance of

relative incomes betweeen agriculture and industry. After a dramatic shift in comparative advantage from agriculture to industry occurred, reflecting the rapid decline in relative real labor productivity in agriculture, average per capita farm income decreased relative to nonfarm incomes (Hayami, p. 22). However, the introduction of price supports in the postwar period allowed per capita farm incomes to increase faster than nonfarm incomes, despite the continued decline in relative productivity of agriculture. Indeed, with rapid increases in off-farm incomes in farm households, relative farm incomes in fact had become higher by 1980. (See de Gorter and Tsur for a theoretical explanation of why policy may reverse relative incomes.)

The validity of our model is also tested in terms of the level of the nominal rates of protection (NRPs) for eighteen developing countries studied by Krueger, Schiff, and Valdes. The NRPs are used as a proxy for the level of transfers between the rural and urban sector. The data cover the average of two periods (1975–79 and 1980–84) and involve several agricultural sectors including exportables and importables. The average NRPs are in percentages and refer to total protection that include both direct (sector specific) and indirect (macro) protection.

Urban income is proxied by nonagricultural GDP (billions of local currency) converted into U.S. dollars, deflated by the GDP deflator (1980 = 100) and divided by urban population. Nonagricultural GDP is determined by multiplying total GDP (from IMF Financial Statistics [monthly]) and subtracting the agricultural share of GDP (obtained from the World Bank Development Report [annual]). Exchange rates, GDP deflators, and total population are all obtained from the IMF Financial Statistics (monthly). The variable indicating the category of income levels for a country is obtained from the World Bank Development Report. Rural population is obtained from the FAO Agrostat database (obtained via personal correspondence). The variable LC represents arable land area for 1985 (obtained from the FAO Production Yearbook [annual]) and is divided by the rural population.

The explanatory variables include the difference in per capita GDP between the agricultural and urban sectors (Y_r and Y_u, respectively) as a proxy for endowment income differentials; the ratio of urban to rural population (R); a binary variable to capture the influence of net trade ($DX = 0, 1$ for importables and exportables, respectively); a binary variable $DR = 1$ if the commodity is rice; per capita arable land (LC); and an indicator variable $INCDUM = 1$ if low-income country; $= 2$ if middle-income country; and $= 3$ if upper-middle income country.

$$\underset{(-11.8)}{NRP = -88} \quad \underset{(-2.4)}{- 3.46\,(Y_r - Y_u)} + \underset{(3.3)}{11.8R}$$
$$\underset{(-2.4)}{- 12.1DX} + \underset{(6.2)}{38DR} - \underset{(-4.5)}{11.3LC} + \underset{(4.6)}{20INCDUM}$$
$$\bar{R}^2 = 0.72, \qquad NOBS = 67.$$

The asymptotic t-statistics are given in parentheses. All variables have the anticipated signs. The per capita GDPs are proxies for endowment incomes. This income gap variable reflects the difference in the average productivity across countries between agriculture and the nonagricultural sectors. Because the income gap is affected by the NRP, these are jointly determined variables and an instrument is used for the actual income gap variable in the above regression equation.[3]

In addition to variations in the productivity between the urban and rural sectors, a measure of endowments in the rural sector (per capita arable land LC) is included to capture the impact of fixed capital on the endowment incomes of agriculture. The per capita GDP in the agricultural and nonagricultural sectors, Y_r and Y_u, indicate the effects of produced capital on endowment incomes. A similar measure of the effect of fixed capital on urban endowments is not readily available but might be inlcuded in future research proxies, such as natural resource endowments or education levels of the working force. A 0, 1 dummy variable to test for structural differences between the two time periods was rejected.

Consistent with our model, the negative coefficient on $(Y_r - Y_u)$ indicates that a decrease in the rural-urban income gap will result in an increase in agricultural protection. For example, the dramatic growth in the manufacturing sectors of the newly industrialized countries would generate the observed increase in agricultural support. This empirical evidence supports the notion that governments respond to relative endowment income differences in setting price policies.[4]

---

[3] This instrument is the prediction from the regression of the income gap on the other exogenous variables in the equation plus rural and urban population, average per capita income, and binary variables for wheat and corn.

[4] The literature has generally demonstrated a correlation between protection and average per capita national income. Because there is a correlation of 0.68 between average per capita income and our income gap variable, we included the average income as an explanatory variable as well. The sign and significance on all of our right-hand-side variables did not change and the sign on average per capita income was negative and statistically insignificant.

The positive coefficient of R implies a positive relationship between the transfer, as reflected by the NRP, and the ratio of the urban-rural population R (compare proposition 2). As predicted by the model, the level of transfers to agriculture is lower for exportables (DX) and higher for the inelastic demand sector rice (DR). Rice represents the staple food in most diets in developing countries and hence can be regarded as most inelastic in demand. Finally, $INCDUM$ is a proxy for the degree of industrialization among countries. Although all variables are proxies for those developed in the theoretical model, the empirical results are consistent with the prediction of our model analyzing the interaction between support-demanding politicians and support-supplying individuals.

Concluding Comments

This paper uses a model of politician-voter interaction to explain some observed patterns of government intervention in agriculture. The manner in which members form their political opinions is assumed to depend on relative income and on redistributed income. The relative income factor motivates policies that result in an egalitarian income distribution. Such equity considerations by politicians are not driven by social concerns or ethical reasoning. Rather, it is in the self-interest of politicians to provide such an outcome. The redistributed income factor motivates policies that maintain the status quo in which no wealth transfers take place. The final outcome is somewhere in between, depending on the weights individuals place on the relative income and the redistributed income motives when forming their political opinions.

Several generalizations can be made to refine this basic structural model. First, our model assumes that the functions $G(\cdot)$ and $F(\cdot)$ are the same between groups. However, Downs and many studies later (e.g., Magee, Brock, and Young) emphasize how uncertainty and differential information affect voter preferences and government policies.

Another important assumption made in our model is that politicians maximize the sum of individual support functions as specified in equation (7). Additive political support is an unrealistic assumption because the political process and institutions normally transform the economic basis of policy costs/benefits into political costs/benefits. An important example is the differential effects of proportional representation in GER and a geographically based parliamentary system in the UK.

Finally, several other potential modifications to our model can enrich its predictions. The weights W_1 and W_2 can be made endogenous and vary between the urban and rural groups. An hypothesis is that poorer people are less concerned with relative income so W_2 would be lower. Likewise, independent of relative or redistributed incomes, it may well be that farmers are more concerned about relative incomes than the urban sector.[5] Expanding the number of groups in each of the rural and urban sectors may enhance the quality of the model, e.g., taxpayers versus consumers in the urban sector or landowners versus landless laborers in the rural sector. Inclusion of public good policies so important to agriculture would also be a priority for future research.

[Received December 1989; final revision received January 1991.]

References

Anderson, K., and Y. Hayami, eds. *The Political Economy of Agricultural Protection: East Asia in International Perspective*. Sydney, Australia: Allen and Unwin, 1986.

Anderson, K., and R. Tyers. "Agricultural Protection Growth in Advanced and Newly Industrialized Countries" *Agriculture and Governments in an Interdependent World*, ed. A. Maunder, Aldershot: Gower, 1990.

Baldwin, R. E. "The Political Economy of Trade Policy." *J. Econ. Perspectives* 3(1989):119–135.

Bale, M. D., and E. Lutz. "Price Distortions in Agriculture and Their Effects: An International Comparison." *Amer. J. Agr. Econ.* 63(1981):8–22.

Balisacan, A., and J. Roumasset. "Public Choice of Economic Policy: The Growth of Agricultural Protection." *Weltwirtschaftliches Archiv* 123(1987):232–47.

Becker, G. "A Theory of Competition among Pressure Groups for Political Influence." *Quart. J. Econ.* 98(1983):371–400.

Binswanger, H., and P. Scandizzo. "Patterns of Agricultural Protection." Washington DC: World Bank Rep. ARU 15, 1983.

Brock, W. A., and S. P. Magee. "The Economics of Special Interest Politics: The Case of the Tariff." *Amer. Econ. Rev.* 68(1978):246–50.

[5] The support function could also shift with the method or instrument type used to implement the transfer. For example, in times of budget deficits, it is very possible that expenditure-type programs, like export subsidies for grains in the United States, are more politically sensitive than direct consumer-to-farmer transfers as in the U.S. sugar program.

de Gorter, Harry. "Agricultural Policies: A Study in Political Economy." Ph.D. thesis, University of California, Berkeley, 1983.

de Gorter, H., and Y. Tsur. "The Political Economy of Agricultural Policy and Trade." *Imperfect Competition and Political Economy: The New Trade Theory in Agricultural Trade Research*, ed. C.A. Carter, A.F. McCalla, and J.A. Sharples. Boulder CO: Westview Press, 1990.

de Janvry, A. "Why Do Governments Do What They Do? The Case of Food Price Policy." *The Role of Markets in the World Food Economy*, ed. D. G. Johnson and G. Edw. Schuh Boulder CO: Westview Press, 1983.

Downs, A. *An Economic Theory of Democracy*. New York: Harper and Row Publishers, 1957.

Gardner, B. L. "Causes of U.S. Farm Commodity Programs." *J. Polit. Econ.* 95(1987):290–310.

Hayami, Y. *Japanese Agriculture Under Siege*. New York: St. Martin's Press, 1988.

Honma, M., and Y. Hayami. "Structure of Agricultural Protection in Industrial Countries." *J. Int. Econ.* 20(1986):115–29.

Johnston, B. F., and J. W. Mellor. "Agriculture in Economic Development." *Amer. Econ. Rev.* 51(1961):566–93.

Krueger, A., M. Schiff, and A. Valdes. "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economywide Policies." *World Bank Econ. Rev.* 2(1988):255-72.

Magee, S. P., W. A. Brock, and L. Young. *Black Hole Tariffs and Endogenous Policy Theory*. Cambridge: Cambridge University Press, 1989.

Olson, M. "Space, Organization and Agriculture." *Amer. J. Agr. Econ.* 67(1985):928–37.

——. "The Exploitation and Subsidization of Agriculture in the Developed and Developing Countries." *Agriculture in a Turbulent World Economy*, ed. A. Maunder and U. Renborg, pp. 49–59. Aldershot: Gower, 1986.

Peltzman, S. "Toward a More General Theory of Regulation." *J. Law and Econ.* 19(1976):211–40.

Runciman, W. G. *Relative Deprivation and Social Justice*. London: Routledge and Kegan Paul, 1966.

Schultz, T. W. "Reckoning the Economic Achievements and Prospects of Low Income Countries." The Fifth James C. Snyder Memorial Lecture in Agricultural Economics, Purdue University, 22 Feb. 1979.

Sen, A. "Poverty: An Ordinal Approach to Measurement." *Econometrica* 44(1976):219–31.

Staiger, R. W., and G. Tabellini. "Discretionary Trade Policy and Excessive Protection." *Amer. Econ. Rev.* 77(1987):823–37.

U.S. Department of Agriculture (USDA), Economic Research Service, Agriculture and Trade Analysis Division. *Estimates of Producer and Consumer Subsidy Equivalents*. Washington DC, April 1988.

Yitzhaki, S. "Relative Deprivation and the Gini Coefficient." *Quart. J. Econ.* 94(1979):321–24

Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation

Michael Hanemann, John Loomis, and Barbara Kanninen

The statistical efficiency of conventional dichotomous choice contingent valuation surveys can be improved by asking each respondent a second dichotomous choice question which depends on the response to the first question—if the first response is "yes," the second bid is some amount greater than the first bid; while, if the first response is "no," the second bid is some amount smaller. This "double-bounded" approach is shown to be asymptotically more efficient than the conventional, "single-bounded" approach. Using data from a survey of Californians regarding their willingness to pay for wetlands in the San Joaquin Valley, we show that, in a finite sample, the gain in efficiency can be very substantial.

Key words: contingent valuation, wetlands, wildlife, willingness to pay.

The contingent valuation method (*CVM*) is one of the standard approaches for valuing nonmarketed resources, such as recreation, wildlife, and environmental quality. Initially, a bidding format was used to elicit willingness to pay (Randall, Ives, and Eastman). In some sense this traditional bidding method and the newer single-bound dichotomous choice questions represent bipolar ends of a continuum. At the bidding end, the respondent is asked a series of dichotomous choice questions until some point estimate of willingness to pay (*WTP*) is reached. At the other end, in the single-bound dichotomous choice *CVM*, pioneered by Bishop and Heberlein, only one dichotomous choice question is asked, and the dollar amount is treated as a threshold. If the good is valued more highly than the threshold dollar amount, the person answers "yes," otherwise "no." While this approach is easier on the respondent, it is statistically less efficient and requires a larger sample to attain a given level of precision.[1]

Our aim here is to show how the statistical efficiency of dichotomous choice *CVM* can be improved by asking the respondent to engage in two rounds of bidding: participants respond to a first dollar amount and then face a second question involving another dollar amount, higher or lower depending on the response to the first question. This "double-bounded" *CVM* approach was first proposed by Hanemann (1985) and Carson and first implemented by Carson, Hanemann, and Mitchell.[2] We describe the maximum likelihood (*ML*) estimation of this model, compare it with the *ML* estimation of the

Michael Hanemann is an associate professor of agricultural and resource economics at the University of California, Berkeley; John Loomis is an associate professor of environmental studies and agricultural economics, University of California, Davis; and Barbara Kanninen is a graduate student of agricultural and resource economics, University of California, Berkeley.

Giannini Foundation Paper No. 969 (for identification only).

The authors received partial financial support from the NOAA National Sea Grant College Program under grant number NA89AA-D-SG138, Project No. R/MA-32, through the California Sea Grant College, and in part by the California Resources Agency, and from the University of California Water Resources Center No. W-722. The U.S. Government is authorized to reproduce and distribute for government purposes.

The authors are deeply indebted to Thomas Wegge, of Jones & Stokes Associates, and Michael King, of the Survey Research Center at California State University, Chico, who were their collaborators in the empirical study described in this article. They benefitted greatly from comments by Richard Carson, John Stoll, and others attending the W-133 Regional Research Project session of the Western Regional Science Association's annual meeting in February 1990, where an earlier version of this paper was presented. They also acknowledge helpful comments by two *Journal* referees.

[1] This is noted, for example, by Cameron and by Mitchell and Carson.

[2] Carson, Hanemann, and Mitchell used iteratively re-weighted least squares rather than the *ML* estimation employed here. *ML* estimation was applied to double-bounded data by Carson and Mitchell. Cameron and James applied the double-bounded model to *CV* data obtained using a payment card; a similar model was estimated by Bergland and Kriesel.

conventional, single-bounded model, and derive the asymptotic gain in efficiency. This theoretical analysis is followed by a *CVM* survey of Californians regarding their *WTP* for protection of wetlands and wildlife habitat in the San Joaquin Valley. Both the single- and double-bounded models are fitted to this data. Computations of confidence intervals for a *WTP* measure permit a direct, empirical assessment of the gain in efficiency associated with the double-bounded model.

Theory

Single-Bounded Model

The conventional, single-bound *CVM* survey involves asking an individual if she would pay some given amount, B, to secure a given improvement in environmental quality. The probability of obtaining a "no" or a "yes" response can be represented, respectively, by

$$\pi^n(B) = G(B; \theta), \tag{1}$$

$$\pi^y(B) = 1 - G(B; \theta), \tag{2}$$

where $G(\bullet; \theta)$ is some statistical distribution function with parameter vector θ. As pointed out in Hanemann (1984), this statistical model can be interpreted as a utility-maximization response within a random utility context, where $G(\bullet; \theta)$ is the cumulative density function (cdf) of the individual's true maximum *WTP* because utility maximization implies

$$\Pr\{\text{No to } B\} \Leftrightarrow \Pr\{B > \text{maximum } WTP\},$$

$$\Pr\{\text{Yes to } B\} \Leftrightarrow \Pr\{B \leq \text{maximum } WTP\}.$$

In Bishop and Heberlein's pioneering study, $G(\bullet; \theta)$ is the log-logistic cdf:

$$G(B) = [1 + e^{a - b(\ln B)}]^{-1}, \tag{3}$$

where $\theta \equiv (a, b)$. Another alternative is the logistic cdf:[3]

$$G(B) = [1 + e^{a - b(B)}]^{-1}. \tag{4}$$

While other estimation techniques have equivalent asymptotic properties, it is convenient to focus on the *ML* estimator. Consider N participants in the single-bounded experiment, and let B_i^S be the bid offered to the ith participant. Then, the log-likelihood function for this set of responses is

$$\begin{aligned} \ln L^S(\theta) &= \sum_{i=1}^{N} \{d_i^y \ln \pi^y(B_i^S) \\ &\quad + d_i^n \ln \pi^n(B_i^S)\} \\ &= \sum_{i=1}^{n} \{d_i^y \ln [1 - G(B_i^S; \theta)] \\ &\quad + d_i^n \ln G(B_i^S; \theta)\}, \end{aligned} \tag{5}$$

where d_i^y is 1 if the ith response is "yes" and 0 otherwise, while d_i^n is 1 if the ith response is "no" and 0 otherwise. The *ML* estimator, denoted $\hat{\theta}^S$, is the solution to the equation $\partial \ln L^S(\hat{\theta}^S)/\partial\theta = 0$. This estimator is consistent (though it may be biased in small samples) and asymptotically efficient.[4] Thus, the asymptotic variance-covariance matrix of $\hat{\theta}^S$ is given by the Cramer-Rao lower bound

$$V^S(\hat{\theta}^S) = \left[-E\frac{\partial^2 \ln L^S(\hat{\theta}^S)}{\partial\theta\,\partial\theta'}\right]^{-1} \equiv I^S(\hat{\theta}^S)^{-1}, \tag{6}$$

where $I^S(\hat{\theta}^S)$ is the information matrix.

Double-Bounded Model

Now consider an alternative format in which each participant is presented with two bids. The level of the second bid is contingent upon the response to the first bid. If the individual responds "yes" to the first bid, the second bid (to be denoted B_i^u) is some amount greater than the first bid ($B_i < B_i^u$); if the individual responds "no" to the first bid, the second bid (B_i^d) is some amount smaller than the first bid ($B_i^d < B_i$).[5]

Thus, there are four possible outcomes: (*a*) both answers are "yes"; (*b*) both answers are "no"; (*c*) a "yes" followed by a "no"; and (*d*) a "no" followed by a "yes." The likelihoods of

[3] Both distributions correspond to forms of the logit model. If the lognormal or normal cdf were used in place of (3) or (4), this would correspond to forms of the probit model. Other distribution functions could readily be employed, although logit and probit models are the most common to date.

[4] See Amemiya. For logit and probit models, McFadden and Haberman established the global concavity of the log-likelihood function in equation (5).

[5] This is easy to implement in a telephone or in-person interview; an example of how it might be implemented in a mail survey is given by Wegge, Hanemann, and Strand.

these outcomes are π^{yy}, π^{nn}, π^{yn}, and π^{ny}, respectively. Under the assumption of a utility-maximizing respondent, the formulas for these likelihoods are as follows. In the first case, we have $B_i^u > B_i$ and

$$(7) \qquad \pi^{yy}(B_i, B_i^u) = \Pr\{B_i \leq \max WTP \text{ and } B_i^u \leq \max WTP\}$$
$$= \Pr\{B_i \leq \max WTP | B_i^u \leq \max WTP\} \Pr\{B_i^u \leq \max WTP\}$$
$$= \Pr\{B_i^u \leq \max WTP\} = 1 - G(B_i^u; \theta),$$

since, with $B_i^u > B_i$, $\Pr\{B_i \leq \max WTP | B_i^u \leq \max WTP\} \equiv 1$. Similarly, with $B_i^d < B_i$, $\Pr\{B_i^d \leq \max WTP | B_i \leq \max WTP\} \equiv 1$. Hence,

$$(8) \quad \pi^{nn}(B_i, B_i^d) = \Pr\{B_i > \max WTP \text{ and } B_i^d > \max WTP\} = G(B_i^d, \theta).$$

When a "yes" is followed by a "no," we have $B_i^u > B_i$ and

$$(9) \quad \pi^{yn}(B_i, B_i^u) = \Pr\{B_i \leq \max WTP \leq B_i^u\} = G(B_i^u; \theta) - G(B_i; \theta);$$

and when a "no" is followed by a "yes," we have $B_i^d < B_i$ and

$$(10) \quad \pi^{ny}(B_i, B_i^d) = \Pr\{B_i \geq \max WTP \geq B_i^d\} = G(B_i; \theta) - G(B_i^d; \theta).$$

In (9) and (10), the second bid allows the researcher to place both an upper and a lower bound on the respondent's unobserved true *WTP*, while in (7) and (8) the second bid sharpens the single bound—it raises the lower bound or lowers the upper bound.[6] Given a sample of N respondents, where B_i, B_i^u, and B_i^d are the bids used for the ith respondent, the log-likelihood function takes the form

$$(11) \quad \ln L^D(\theta) = \sum_{i=1}^{N} \{d_i^{yy} \ln \pi^{yy}(B_i, B_i^u) + d_i^{nn} \ln \pi^{nn}(B_i, B_i^d) + d_i^{yn} \ln \pi^{yn}(B_i, B_i^u) + d_i^{ny} \ln \pi^{ny}(B_i, B_i^d)\},$$

where d_i^{yy}, d_i^{nn}, d_i^{yn}, and d_i^{ny} are binary-valued indicator variables and the formulas for the corresponding response probabilities are given by (7)–(10). The *ML* estimator for the double-bounded model, $\hat{\theta}^D$, is the solution to the equation $\partial \ln L^D(\hat{\theta}^D)/\partial\theta = 0$. The asymptotic variance-covariance matrix for $\hat{\theta}^D$ is given by the analog of (6):

$$(12) \quad V^D(\hat{\theta}^D) = \left[-E\frac{\partial^2 \ln L^D(\hat{\theta}^D)}{\partial\theta\, \partial\theta'}\right]^{-1} \equiv I^D(\hat{\theta}^D)^{-1}.$$

The Estimators Compared

The efficiency of the single- and double-bounded *ML* estimators can be compared by examining their respective information matrices. Differentiating the log-likelihood functions and then taking expectations yields

$$I^S(\theta) = \sum_i I(B_i^S; \theta), \text{ and}$$
$$I^D(\theta) = \sum_i I(B_i, B_i^u, B_i^d; \theta),$$

where, for the ith observation,

$$(13) \quad I^S(B_i^S; \theta) = \frac{G_\theta(B_i^S; \theta) G_\theta(B_i^S; \theta)'}{G(B_i^S; \theta) \cdot [1 - G(B_i^S; \theta)]},$$

while

$$(14) \quad I^D(B_i, B_i^u, B_i^d; \theta) = \frac{G_\theta(B_i^u; \theta) G_\theta(B_i^u; \theta)'}{\pi^{yy}} + \frac{G_\theta(B_i^d; \theta) G_\theta(B_i^d; \theta)'}{\pi^{nn}} + \frac{QQ'}{\pi^{yn}} + \frac{RR'}{\pi^{ny}},$$

where π^{yy}, π^{nn}, π^{yn}, and π^{ny} are the probabilities on the right-hand side of (7)–(10) and the vectors Q and R are defined by $Q \equiv [G_\theta(B_i^u; \theta) - G_\theta(B_i; \theta)]$ and $R \equiv [G_\theta(B_i; \theta) - G_\theta(B_i^d; \theta)]$.

Our comparison of $\hat{\theta}^S$ and $\hat{\theta}^D$ will focus on three cases, corresponding to different ranges of bid values: in one case, the two estimators are equally efficient; in another, the double-bounded estimator is unambiguously more efficient; and,

[6] In the application to be reported below, double bounds were obtained for between a third and a half of the respondents, depending on the program being evaluated.

in the third case, the ranking of efficiencies is indeterminate.

First is the degenerate case where, for all i, $B_i = B_i^S$, $B_i^u = \infty$, and $B_i^d = 0$. In that case the double-bounded model collapses to the single-bounded model and one has $L^S(\theta) = L^D(\theta)$, $\hat{\theta}^S = \hat{\theta}^D$, and $V^S(\theta) = V^D(\theta)$.[7] Thus, if the second, follow-up, bid in a double-bounded experiment is made sufficiently large when the response to the first bid is a "yes," and sufficiently small when the response to the first bid is a "no," this ensures that it yields no additional information beyond that already contained in the response to the first bid. Hence, one can always mimic the outcome of a single-bounded experiment by choosing sufficiently extreme follow-up bids in a double-bounded experiment. As a corollary, this implies that, when the bids in single- and double-bounded experiments are optimally designed, the most efficient design for the double-bounded model will yield more efficient estimates of θ than the most efficient design for the single model.[8]

Second is the nondegenerate case where, for all i, $B_i = B_i^S$, $B_i < B_i^u < \infty$, and $0 < B_i^d < B_i$. That is, the bids from the single-bounded experiment are the same as the starting bids in a double-bounded experiment which then has non-extreme follow-up bids. In that case, subtraction of (13) from (14) and some manipulation yields the following formula for $\Delta_i \equiv I^D(B_i, B_i^u, B_i^d; \theta) - I^S(B_i^S; \theta)$:

$$\Delta_i = AA'/\gamma + WW'/\delta, \tag{15}$$

where $\gamma \equiv [1 - G(B_i^u; \theta)] \cdot [1 - G(B_i; \theta)] \cdot [G(B_i^u; \theta) - G(B_i; \theta)]$ and $\delta \equiv [G(B_i; \theta) - G(B_i^d; \theta)] \cdot G(B_i; \theta) \cdot G(B_i^d; \theta)$ are positive scalars, and A and W are vectors given by $A \equiv [G_\theta(B_i; \theta) \cdot (1 - G(B_i^u; \theta)) - G_\theta(B_i^u; \theta) \cdot (1 - G(B_i; \theta))]$ and $B \equiv [G_\theta(B_i^d; \theta) \cdot G(B_i; \theta) - G_\theta(B_i; \theta) \cdot G(B_i^d; \theta)]$. Because both AA' and WW' are positive semidefinite matrices, it follows that $I^D(\theta) \geq I^S(\theta)$ and $V^D(\theta) \leq V^S(\theta)$: $\hat{\theta}^D$ is asymptotically more efficient than $\hat{\theta}^S$.

Both of the preceding results rely on the assumption that the initial bid in the double-bounded experiment is the same as the bid in the single-bounded experiment. If this is not the case and $B_i \neq B_i^S$, then the difference Δ_i does not necessarily reduce to a positive semidefinite matrix and the relative efficiency of $\hat{\theta}^D$ versus $\hat{\theta}^S$ is unclear. It could happen, for example, that a single-bounded experiment with a nearly optimal design of bid B_i^S dominates a double-bounded experiment with a different, and poor, design of bid B_i.[9]

Application

The double-bounded approach was employed in a *CVM* study conducted for the Interagency San Joaquin Valley Drainage Program that focused on *WTP* for protecting wildlife and wetlands habitat in California's San Joaquin Valley (Jones and Stokes Associates). The survey involved a combination of mail and telephone media. Initial telephone calls were made to a random sample of households based on random digit dialing. The households were asked to participate in a survey and specify a time at which they could be called back in order to record their responses to the questionnaire. The questionnaire was mailed out and then the household was contacted at the appointed time, with additional phone calls made as needed.[10]

This format provides quality control with respect to the respondents' comprehension of the questionnaire and flexibility with regard to instrument design. Not every question in the script for the telephone interview needs to be included in the version of the questionnaire that is mailed out. This is a convenient way to handle complex branching. It also facilitates the implementation of the double-bounded *CV* model: The mail-out questionnaire contains only the first bid; while the second bid, which is contingent on the response to the first, is incorporated into the telephone script, as illustrated below.

The *CV* study focused on five environmental programs.[11] The first two related to wetlands habitat in the San Joaquin Valley. One program would maintain wetlands habitat at current con-

---

[7] This follows since $\lim_{B\to\infty} G(B; \theta) = 1$, $\lim_{B\to 0} G(B; \theta) = 0$, and $\lim_{B\to\infty} G_\theta(B; \theta) = \lim_{B\to 0} G_\theta(B; \theta) = 0$. Substituting these into (5), (11), (13), and (14) yields the result. Note the assumption here that the lower end of the support of $G(B; \theta)$ is zero—i.e., *WTP* is nonnegative. If a negative *WTP* is possible, then the degenerate case involves setting $B_i^d = -\infty$ rather than $B_i^d = 0$.

[8] This is because the most efficient design for the single-bounded experiment can always be mimicked, and then improved upon, with an appropriate choice of bids in a double-bounded experiment. For an analysis of optimal bid design in single-bounded models, see Minkin, Chaloner and Larntz, and Alberini and Carson; for optimal bid design in double-bounded models, see Kanninen.

[9] Our earlier result establishes that this cannot happen when both bids are optimally designed.

[10] A more detailed description of the survey is provided in Jones and Stokes Associates, together with a copy of the questionnaire and the scripts for the telephone interviews.

[11] As explained in the introduction to the mail-out questionnaire, the context for these programs is the long-term decline in the San Joaquin Valley's wetlands because of farmland conversion and water resources development since the 1850s.

ditions; without this action, wetlands acreages in the Valley will decrease. The other program would go beyond maintenance to improve wetland habitat above current levels. There was a similar pair of programs relating to the exposure of wildlife to contaminated agricultural drainage water stored in evaporation ponds at various locations in the valley: One program would prevent any increase in exposure of wildlife to contamination, thereby maintaining current conditions, and the other program would improve conditions by reducing wildlife exposure to contaminated waters. The last program dealt with restoring flows in the upper San Joaquin River, below Friant Dam, which affect salmon and other fish in the river and wildlife and vegetation along the river banks. This program would increase flows and fish populations along the stretch of the river.

The mail-out questionnaire informed subjects that they would be asked to consider these five programs, then described each in some detail and asked the discrete choice *WTP* question. This question was intended to reflect the household's total annual *WTP* for the program, including recreation use, option, and existence values (Randall and Stoll; Loomis, Peterson, and Sorg). The format was a voter referendum, and the payment vehicle was additional taxes. In the case of wetland maintenance, for example, the text in the mail-out questionnaire read: "If the wetlands habitat and wildlife *maintenance* program were the only program you had an opportunity to vote on, and this maintenance program cost every household in California $___ each year in additional taxes, would you vote for it?" In the telephone interview, the interviewer then followed up with: "What if the cost were $___?" The same wording sequence was used with the other programs.

The bids used for the wetlands maintenance program are displayed in table 1. The first column shows the initial bid (B) that was printed in the mail-out questionnaire, B^d is the second bid used by the telephone interviewer if the response to the first bid was "no"; B^u is the second bid if the response was "yes." There were five separate sets of bids, distributed randomly across the participants in the survey.[12] These bids were selected on the basis of results obtained in a very small pretest, from which an informal estimate of the *WTP* distribution, $G(B; \theta)$, was derived. The bids correspond to upper and lower quantiles of this distribution, arrayed around the median.

The survey was conducted in May 1989, by a professional survey organization. Three geographical areas were targeted: the San Joaquin Valley; the rest of California; and Oregon, Washington, and Nevada, which are neighboring states along the Pacific Flyway. The survey organization established contact with 1,960 households containing an eligible respondent. Of these, 1,239 agreed to participate (63.1%).[13] After the questionnaire had been mailed, the survey company was able to contact 1,058 of these households within the time available; of these, 1,004 completed interviews (94.9%), while 54 refused to participate. The distribution of the completed interviews, by area, was San Joaquin Valley, 227; rest of California, 576; and out-of-state, 201.

Results

For the purpose of examining the statistical efficiency of double- versus single-bounded dichotomous choice *CV* questions, the data collected in the survey were used to estimate two models. A conventional, single-bounded model was estimated from the responses to the first bid; then, a double-bounded model was estimated from the responses to both the first and second bids. Both models were estimated by maximum

Table 1. Alternative Bids for the Wetlands Maintenance Program

B	B^d	B^u
40	25	80
50	25	110
65	30	125
80	40	.125
110	55	170

Note: B is initial bid (annual increment in household taxes, in dollars); B^d is second bid if response to first bid was "no." B^u is second bid if response to first bid was "yes."

[12] For wetlands improvement there were 18 sets of bids, each higher to some degree than the corresponding wetlands maintenance bids, with a maximum B^u of $375. There were similar sets of bids for the two wildlife contamination programs (the highest bid was $500) and the salmon improvement program (the highest bid was $225). These bids are exhibited in Jones and Stokes Associates.

[13] Of the 721 refusals, 202 hung up immediately after the interviewer started the introduction without further interaction, 90 said they were too busy to talk now, 51 were unwilling to give out their address, and 28 said that they do not participate in surveys. Of the rest, 154 were not probed for their reason, 146 said that they were not interested, 14 expressed negative views about the environment or the government's management of natural resources, and 36 gave various miscellaneous reasons other than those listed above.

likelihood, using the likelihood function in (5) for the single-bounded model and that in (11) for the double-bounded model.[14]

In both cases, a variety of models were estimated, using the logistic cdf, (4), as well as the log-logistic cdf, (3), both with and without attitudinal and sociodemographic variables added to the intercept term in the exponents of (3) and (4). These models were estimated separately for each subsample. The full set of results is reported in Jones and Stokes Associates. To save space, we report here the results for the sample of households from the rest of California, using the logistic model without covariates; the other results are very similar and lead to the same conclusions.[15] The estimates of the intercept and the slope coefficient in (4) are presented in table 2 for both the single- and double-bounded models.

In the notation employed above, this application constitutes a case where $B_i = B_i^S$; hence, the coefficient estimates from the double-bounded model are asymptotically more efficient than those from the single-bounded model. What do our empirical results show about the relative efficiencies in a finite sample? This will be considered here from three perspectives: The precision of the estimates of the coefficients a and b; the goodness of fit of the estimated *WTP* model; and the precision of the estimates of welfare measures derived from the underlying coefficient estimates.

Table 3 presents the estimated variance-covariance matrices for the single- and double-bounded *ML* estimates of a and b corresponding to the wetland maintenance program; the results for all the other programs are very similar. The estimated variance of b is smaller by a factor of about 10 in the double-bounded model compared to the single-bounded model, the variance of a is smaller by a factor of 3, and the covariance term is smaller by a factor of 6. This translates into much higher t-statistics for the double-bounded model, as table 2 shows. Also, both measures of goodness of fit—the chi-squared statistic and McFadden's pseudo R^2—are substantially higher for the double-bounded model. For example, for the contamination maintenance program the pseudo-R^2 statistic is 0.12 for the double-bounded model versus 0.03 for the single-bounded model.

The ultimate aim in fitting a statistical model

[14] The program GQOPT was used to maximize the likelihood function for the double-bounded model; both GQOPT and the logit module of SHAZAM were used for the single-bound model, and they gave identical results. In addition to GQOPT, packages such as GAUSS, LIMDEP, SAS, and SYSTAT provide maximization routines. A special subroutine called SURVIVAL is available for SYSTAT users to estimate the double-bounded model based on the lognormal, log-logistic and Weibull distributions.

[15] Indeed, a likelihood ratio test showed that the data from households in the rest of California could be pooled with the data from households in the San Joaquin Valley.

Table 2. Coefficient Estimates for Single- and Double-Bounded Models

	Single-Bounded Model		Double-Bounded Model	
	Intercept ($\hat{a}$)	Slope ($-\hat{b}$)	Intercept ($\hat{a}$)	Slope ($-\hat{b}$)
Wetland maintenance				
Coefficient estimate	2.68	−0.0107	3.77	−0.0249
t-statistic	(6.51)	(−1.91)	(16.74)	(−13.94)
χ^2/pseudo R^2	3.56	0.01	161.48	0.16
Wetland improvement				
Coefficient estimate	1.94	−0.0077	3.042	−0.0123
t-statistic	(6.76)	(−3.97)	(17.73)	(−14.75)
χ^2/pseudo R^2	16.10	0.03	281.18	0.23
Contamination maintenance				
Coefficient estimate	3.35	−0.0158	3.61	−0.0194
t-statistic	(7.62)	(−3.35)	(17.49)	(−14.57)
χ^2/pseudo R^2	11.14	0.03	115.48	0.12
Contamination improvement				
Coefficient estimate	1.74	−0.00634	2.87	−0.0095
t-statistic	(6.40)	(−3.96)	(17.74)	(−14.86)
χ^2/pseudo R^2	16.07	0.03	347.74	0.28
Salmon improvement				
Coefficient estimate	2.18	−0.0068	3.45	−0.0192
t-statistic	(6.10)	(−1.68)	(16.85)	(−14.04)
χ^2/pseudo R^2	2.77	0.01	289.78	0.25

Table 3. Estimated Variance-Covariance Matrix, Wetland Maintenance Program

$$\begin{bmatrix} 1.69 \times 10^{-1} & -2.16 \times 10^{-3} \\ -2.16 \times 10^{-3} & 3.10 \times 10^{-5} \end{bmatrix} \begin{bmatrix} 0.51 \times 10^{-1} & -3.61 \times 10^{-4} \\ -3.61 \times 10^{-4} & 3.19 \times 10^{-6} \end{bmatrix}$$

(*a*) Single-bounded model (*b*) Double-bounded model

to the *CV* responses is to derive a summary measure of the *WTP* distribution $G(B; \theta)$. The summary statistic is a function of the parameters in θ. For the logistic model (4), for example, the mean and median *WTP* are given by $WTP^* = a/b$, while the truncated mean is given by Hanemann (1989) as $WTP^+ = \ln(1 + e^a)/b$. For the coefficient values in table 2, there is virtually no difference between these two alternative welfare measures across all programs. For the wetland maintenance program, for example, the single-bounded coefficients yield estimates of $WTP^* = \$250$ and $WTP^+ = \$257$; the double-bounded coefficients yield lower, but equally close, values of $WTP^* = \$151$ and $WTP^+ = \$152$. For simplicity, we focus here on the estimates of WTP^+, which are reported for both models in table 4.[16]

Since these are derived from the *ML* estimates of a and b, they are random variables; their distribution depends on that of the *ML* estimators, which are asymptotically normal with variance-covariance matrices such as those shown in table 3. In order to obtain confidence intervals for the point estimates of WTP^+, we used Krinsky and Robb's Monte Carlo simulation technique as adapted by Park, Loomis, and Creel. This involved simulating the bivariate normal distribution of a and b, using the *ML* estimates of the coefficients and the variance-covariance matrix, and calculating WTP^+ for each replicate of a and b, thereby generating an empirical distribution function for WTP^+.[17] The 90% confidence interval was obtained by omitting 5% of the observations from both tails. These confidence intervals are shown in table 4. The difference between the single- and double-bounded models is striking. For the wetland improvement program, for example, the confidence interval for WTP^+ is \$231–\$360 for the single-bounded model versus \$235–\$268 for the double-bounded model, approximately a fourfold difference. There is a similar or larger gain in precision for the other programs.

In addition to the tighter confidence interval, the double-bounded model tends to yield a lower point estimate for WTP^+. These two phenomena are related. Observe that the bids in table 1 are low relative to the estimates of WTP^+ in table 4. The initial bids, B, for wetland maintenance were arrayed around \$65, which was our guess at the median *WTP* based on very limited pretest results, while the final estimates of WTP^* and WTP^+ were closer to \$150. This phenomenon

[16] These should not necessarily be regarded as our final assessment of California households' willingness to pay to protect wildlife and wetlands habitat in the San Joaquin Valley because we are conducting additional research with the double-bounded data aimed at exploring other probability distributions for $G(B; \theta)$ and alternative, nonparametric estimators of WTP^+ and WTP^*. The results of that research will be reported separately.

[17] In each simulation, 4,000 replications were employed.

Table 4. Estimates of WTP^+ (\$/yr) for California Households

	Single-Bounded Model		Double-Bounded Model	
Program	Point Estimate	90% Confidence Internal	Point Estimate	90% Confidence Interval
Wetland maintenance	257	167–983	152	123–188
Wetland improvement	269	231–360	251	235–268
Contamination maintenance	214	171–345	187	177–199
Contamination improvement	300	248–431	308	289–331
Salmon improvement	336	206–1,681	181	171–193

occurred with all the programs. An optimal design would have put B closer to WTP^*. Because of this, the great majority of subjects responded "yes" to the initial bids. Given this preponderance of "yes" responses, we could readily infer that WTP^* and WTP^+ were some amount larger than B, but we were hard pressed to determine how much larger.[18] It was only when subjects responded "no" to some of the follow-up bids B^u that we were able to pin down the value of WTP^* or WTP^+. This explains why our single-bounded estimates, which rely only on the response to B, not only had a larger confidence interval but also generated a higher point estimate for WTP^* and WTP^+.[19] It illustrates an advantage of the double-bounded approach, that it can provide an insurance policy against a poor choice of initial bid: B^u recoups against too low a choice of B, and B^d against too high a choice.

One reason why *CV* researchers moved away from the iterative bidding format was concern over starting point bias (Boyle, Bishop, and Welsh). Could the same problem arise with double-bounded *CV* models? To the extent that respondents' weariness with multiple bid iterations is a cause of the starting point bias, this is unlikely to be a factor in double-bounded models with a single follow-up bid. Other possible causes are anchoring and yea-saying. Because the second bid in the double-bounded model is, by design, very different from the first bid, anchoring is unlikely to be a factor here. Yea-saying cannot be ruled out a priori. One test is to examine the proportion of "yes" responses to B^u. In doing this, it must be remembered that the respondents offered B^u are not a random sample of the population: they are the censored sample for whom $WTP \geq B$. Once this is taken into account, it turns out with our data that respondents are significantly less likely to say "yes" to B^u than would be expected on the basis of their responses to the initial bid B, which controverts the hypothesis of yea-saying in the responses to the second bid.

Conclusions

In the first part of this paper we established that the double-bounded dichotomous choice *CV* model is asymptotically more efficient than the single-bounded model. In the second part we found that, for our data set, this result certainly carries over to finite samples: the confidence intervals for summary measures such as WTP^+ were greatly reduced by using the double-bounded model. In this case, adding a follow-up bid to a conventional, dichotomous choice *CV* survey substantially improved the statistical information provided by the data.

[Received April 1990; final revision received December 1990.]

[18] Technically, the function $1 - G(B; \theta^S)$ was relatively flat in the vicinity of the B_i's.

[19] The one case where the single-bounded model did not generate a larger point estimate of WTP^+ (the contamination improvement program) involved the highest initial bids of all programs, some of which were much larger than the final estimate of WTP^+. This case received the smallest fraction of "yes" responses to the initial bids.

References

Alberini, Anna, and Richard T. Carson. "Efficient Threshold Values for Binary Discrete Choice Contingent Valuation Surveys and Economic Experiments." Dep. Econ. Work. Pap., University of California, San Diego, 1990.

Amemiya, Takeshi. *Advanced Econometrics*. Cambridge MA: Harvard University Press, 1985.

Bergland, Olvar, and Warren Kriesel. "Efficient Estimation in Iterated Referendum Formats of the Contingent Valuation Method." Paper presented at AAEA annual meeting, Baton Rouge LA, 30 July–2 Aug. 1989.

Bishop, Richard, and Thomas Heberlein. "Measuring Values of Extra-Market Goods: Are Indirect Measures Biased?" *Amer. J. Agr. Econ.* 61(1979):926–30.

Boyle, Kevin, Richard Bishop, and Michael Welsh. "Starting Point Bias in Contingent Valuation Bidding Games. *Land Econ.* 61(1985):188–94.

Cameron, Trudy. "A New Paradigm for Valuing Non-Market Goods Using Referendum Data." *J. Environ. Econ. and Manage.* 15(1988):355–79.

Cameron, Trudy Ann, and M. D. James. "Efficient Estimation Methods for Use with 'Closed-Ended' Contingent Valuation Survey Data." *Rev. Econ. and Statist.* 69(1987):269–76.

Carson, Richard T. "Three Essays on Contingent Valuation." Ph.D thesis, University of California, Berkeley, 1985.

Carson, Richard T., W. Michael Hanemann, and Robert C. Mitchell. "Determining the Demand for Public Goods by Simulating Referendums at Different Tax Prices." Dep. Econ. Work. Pap., University of California, San Diego, 1986.

Carson, Richard, and Robert Mitchell. *Economic Value of Reliable Water Supplies for Residential Water Users in State Water Project Service Area.* Report to Metropolitan Water District. Los Angeles, 1987.

Chaloner, Kathryn, and Kinley Larntz. "Software for Logistic Regression Experiment Design." *Optimal Design and Analysis of Experiments*, ed. Y. Dodge, V. V. Fedorou, and H. P. Wynn. Amsterdam: Elsevier Science Publishers, 1988.

Haberman, S. *The Analysis of Frequency Data.* Chicago: University of Chicago Press, 1974.

Hanemann, W. Michael. "Some Issues in Continuous- and Discrete-Response Contingent Valuation Studies." *Northeast. J. Agr. Econ.* (1985):5–13.

——. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *Amer. J. Agr. Econ.* 66(1984):332–41.

——. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses Data: Reply." *Amer. J. Agr. Econ.* 71(1989):1057–61.

Jones and Stokes Associates. *Environmental Benefits Study of San Joaquin Valley's Fish and Wildlife Resources.* JSA 87-150, final report, prepared by J. B. Loomis, W. M. Hanemann, and T. C. Wegge. Sacramento CA, 1990.

Kanninen, Barbara J. "Optimal Experimental Design in Contingent Valuation Surveys." Dep. Agr. and Resour. Econ. Work. Pap., University of California, Berkeley, 1990.

Krinsky, I., and A. L. Robb. "On Approximating the Statistical Properties of Elasticities." *Rev. Econ. and Statist.* 68(1986):715–19.

McFadden, Daniel. "Conditional Logit Analysis of Qualitative Choice Behavior." *Frontiers in Econometrics*, ed. P. Zarembka, pp. 105–42. New York: Academic Press, 1974.

Minkin, Salomon. "Optimal Designs for Binary Data." *J. Amer. Statist. Assoc.* 82(1987):1098–1103.

Mitchell, Cameron, and Richard T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method.* Washington DC: Resources for the Future, 1989.

Loomis, John, George Peterson, and Cindy Sorg. "A Field Guide to Wildlife Economic Analysis." *Transactions of 49th North American Wildlife and Natural Resources Conference.* Washington DC: Wildlife Management Institute, 1984.

Park, Timothy, John Loomis, Michael Creel. "Confidence Intervals for Evaluating Benefit Estimates from Dichotomous Choice Contingent Valution Surveys." *Land Economics*, in press.

Randall, Alan, Barry C. Ives, and Clyde Eastman. "Bidding Games for Valuation of Aesthetic Environmental Improvements." *J. Environ. Econ. and Manage.* 1(1974):132–49.

Randall, Alan, and John Stoll. "Existence Value in A Total Valuation Framework." *Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas*, ed. R. Rowe and L. Chestnut. Boulder CO: Westview Press, 1983.

Wegge, Thomas, Michael Hanemann, and Ivar Strand. *An Economic Assessment of Marine Recreational Fishing in Southern California.* U.S. NOAA, National Marine Fisheries Service Tech. Memo. NMFS-SWR-015, 1986.

Some Further Evidence on the Law of One Price: The Law of One Price Still Holds

John Baffes

International trade models often postulate the existence of a representative price, i.e., the price which prevails at all markets. This is known as the "Law of One Price." In this paper, the law of one price is tested for seven commodities among four countries by explicitly considering transaction costs. The empirical evidence suggests that, in most cases, the law of one price cannot be rejected as a maintained hypothesis. Furthermore, for the remaining cases transaction costs seem to cause the failure.

Key words: cointegration, "Law of One Price," stationarity, transaction costs.

International trade models of agricultural commodities often postulate the existence of a representative price, i.e., a price which prevails at all markets. This is known as the "Law of One Price" (LOP). The LOP assumption is crucial, especially in empirical studies, because its violation may invalidate the studies' conclusions. For example, a model of optimal intervention in a specific commodity market, domestic or international, requires a representative price. If an inappropriate price is used, policy recommendations based on such a model will not have the expected effects. This paper focuses on the consistency of the LOP postulate with empirical evidence.

Traditionally, tests of the LOP have applied the following procedure: A commodity price in one country is regressed on the same commodity's price in another country. Then, the slope coefficient is restricted to equal one and (possibly) the intercept term is restricted to equal zero. If such restrictions are not rejected, the conclusion is that the LOP holds. However, such procedures have not yielded favorable results regarding the LOP (e.g., Isard and Richardson among others). Those tests have been criticized on several grounds. For example, Crouhy-Veyrac, Crouhy, and Melitz cite the omission of transfer costs; if these costs were taken into consideration, favorable results regarding the LOP would be derived. More recently, Goodwin, Grennes, and Wohlgenant argued that the price prevailing in one country should be compared with the expected price of the other country; further, they argued that transaction costs should be explicitly incorporated in the model. They used an expectations-augmented model by including transaction costs and found support for the LOP. Protopapadakis and Stoll (1986) tested whether the LOP holds by making an explicit distinction between the short and the long run. They found supportive evidence for the long-run LOP, which is consistent with their earlier findings (Protopapadakis and Stoll 1983). Ardeni challenged the stationarity properties of the prices, tested the LOP as a long-run relationship by using cointegration, and found that in most cases the LOP does not hold.

The objective of this study is to test whether the LOP holds in the long run. Although the procedure used here is the one suggested by Ardeni (i.e., stationarity tests and subsequently cointegration), the particular test differs in two respects: (*a*) the restricted version of the cointegration test is used instead, and (*b*) transportation costs receive special attention as a cause for failure of the LOP. The next section discusses the concepts of the order of integration and cointegration and how they relate to the LOP. Then, an alternative testing procedure is proposed. Empirical results are presented in the second section. The third section extends the model by incorporating transportation costs and discusses some methodological issues. Finally,

---

John Baffes is a graduate research assistant in the Department of Agricultural and Resource Economics, University of Maryland.

The author wishes to thank Pier Giorgio Ardeni, who very kindly provided most of the data used in the analysis. Helpful comments from an anonymous *Journal* referee are greatly appreciated. The author is solely responsible for any remaining errors.

the last section summarizes the major findings and presents directions for future research.

The Law of One Price

Consider two countries, engaging in international trade of one commodity. In its strict sense, the LOP states that the price of this commodity (expressed in common currency unit) should be the same in the two countries if the necessary adjustments with respect to transaction costs have been made. This is a fundamental principle of commodity arbitrage. In this study we test the LOP as a long-run relationship by exploring certain time-series properties of the variables of interest.

Testing the Law of One Price

A starting point for testing the LOP is the determination of the order of integration of the prices being considered. To define the order of integration, consider a series with a finite spectrum which is nonzero at all frequencies. This series is said to be weakly stationary or integrated of order zero, and is denoted as $I(0)$. If the series must be differenced once to become $I(0)$, it is then said to be integrated of order one, $I(1)$. In general, a series that must be differenced d times to become $I(0)$ is called $I(d)$. A major difference between an $I(0)$ and an $I(d)$ ($d > 0$) series is that the $I(0)$ series has a finite mean and variance, while for an $I(d)$ series those magnitudes do not exist. In what follows, the terms stationarity (or stationarity in levels) and $I(0)$ will be used interchangeably, although strictly speaking they do not coincide.[1]

Consider now the price of a specific commodity in two countries at time t expressed in common currency unit, denoted as x_{1t} and x_{2t}^*. Then, distinguish the following three cases:

(*a*) $x_{1t} \sim I(0)$ and $x_{2t}^* \sim I(0)$. Because both prices are $I(0)$, their means and variances exist; this in turn implies that the LOP holds as a long-run relationship as both prices fluctuate around their means.[2] Consideration of the weak version of the LOP implies possible differences in means. Such differences might reflect stationary components such as middleman profits, taxes, and tariffs. This case can be extended in several ways by considering stricter versions of the LOP. For example, one can form the ratio of the variances of prices and then test the hypothesis that this ratio is one. (See Campbell and Shiller for applications of such test.) Alternatively, if prices follow autoregressive (AR) processes, say $x_{1t} \sim AR(n)$ and $x_{2t}^* \sim AR(k)$, the hypothesis of whether $n = k$ can be tested. Finally, it is valid to regress x_{1t} on x_{2t}^* and test the restriction that the slope coefficient equals one and (possibly) the intercept term equals zero, since all properties of traditional testing techniques are applicable. This last test, however, is subject to the assumption that one price is exogenous because, if prices are simultaneously determined, endogeneity problems are present. Finally, it should be mentioned that prices are usually found to be at least $I(1)$.

(*b*) $x_{1t} \sim I(d)$, $x_{2t}^* \sim I(b)$, $d \neq b$. In this case, prices have different orders of integration and the LOP does not hold because at least one of either x_{1t} or x_{2t}^* will exhibit explosiveness. This can be understood if x_{1t} is $I(0)$ and x_{2t}^* is $I(1)$; i.e., x_{2t}^* contains explosive components which cannot be explained by x_{1t} alone.

(*c*) $x_{1t} \sim I(d)$, $x_{2t}^* \sim I(d)$, $d > 0$. Here, both prices have the same order of integration which is greater than zero. Hence, additional information is needed to examine the validity of the LOP. Such information is obtained from the theory of cointegration (Engle and Granger). In simple terms, cointegration states that, even though some explosive pattern characterizes both prices, there might exist a (unique) parameter which brings them together in the long run so that their linear combination is of a lower order of integration than the original series.[3] In such a case, x_{1t} and x_{2t}^* form a cointegrated system. Cointegration has been used extensively in similar concepts. For example Enders (1988), Corbae and Ouliaris, and Taylor and McMahon used cointegration to test the purchasing power parity hypothesis, while Hakkio and Rush, Enders (1989), and Coleman used cointegration to test the efficient market hypothesis in currency markets.

In general, to determine whether x_{1t} and x_{2t}^* are cointegrated, the following regression is formed:

[1] For the exact definition and properties of integrated series, see Granger (1981).

[2] In a similar context, Hamilton and Flavin tested the limitations of domestic government borrowing. In particular they found that U.S. surplus and U.S. internal debt are stationary and concluded that the U.S. government runs a balanced budget in expected value terms.

[3] A proof regarding the uniqueness of the cointegration parameter in the bivariate case can be found in Hendry (p. 202).

(1) $$x_{1t} = \mu + \beta x_{2t}^{*} + \varepsilon_t,$$

where μ and β denote parameters to be estimated. If ε_t is integrated of order $b (b < d)$, x_{1t} and x_{2t}^{*} are said to be cointegrated. For the specific case that $b = 0$, the LOP holds since both prices move together in the long run. (1) needs to be estimated only if β is unknown. This, however, is not the case when the LOP holds. For example, if the variables of interest were the price of a particular stock and its associated dividend or consumption and income, β would represent the rate of return or the marginal propensity to consume, which are unknown parameters. However, if parameter β is known from theory, as with the LOP, there is no need to estimate it. In particular, the LOP postulates that the cointegration parameter is one. In fact, unity is the only value of the cointegration parameter for which the LOP (i.e., the maintained hypothesis) holds. In this case, the cointegration test is transformed into a stationarity test of the difference between the two prices. (This is stated formally in a proposition and a proof reported in the appendix.)[4] Therefore, testing the LOP in the case that x_{1t} and x_{2t}^{*} are both $I(d)$, $d > 0$ is equivalent to taking the following difference:

(2) $$z_t = x_{1t} - x_{2t}^{*},$$

and testing whether z_t, is $I(0)$. Here the problem becomes a unit root test of a univariate case (Engle and Yoo). Testing for cointegration by taking the difference of two variables is common practice.[5] Admittedly, it is the case that if x_{1t} and x_{2t}^{*} are cointegrated, regression (1) "should give an excellent estimate of the true cointegration coefficient" (Granger 1986, p. 219) so that one would prefer (1) over (2). However, this is true in large samples only.[6] This entails that information from economic theory is utilized, leading to the preference of (2) over (1).

The intuitive interpretation of case (*c*), which is the most relevant since all prices are $I(1)$ as will be shown later, is presented in figures 1a through 2b. Figure 1a depicts the price of wheat in Canada and Australia (1966:2–1983:4 time period) and shows that both prices are characterized by an explosive pattern over the time period examined. However, when the price differential is considered (fig. 1b), the explosive patterns observed in figure 1a are no longer present because the price differential has a tendency to return to an earlier value (i.e., the mean) very often. Consider now the case of wool between U.K. and Australia (1966:1–1986:1 time period). Again, an explosive pattern is observed when the levels of prices are taken (fig. 2a). Contrary to the previous case, however, this explosive pattern is preserved when the price differential is considered (fig. 2b). As the empirical evidence will show later (table 3), those two sets of prices represent two polar cases with respect to cointegration properties.

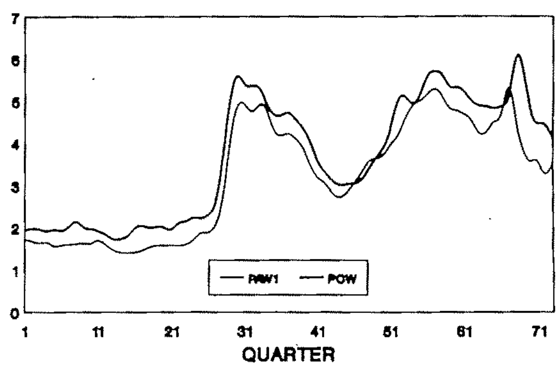


Figure 1a. Wheat price in Canada and Australia

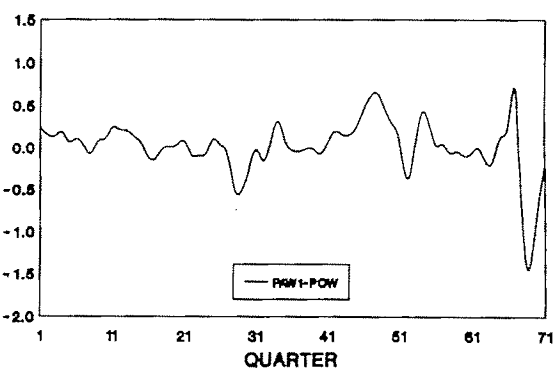


Figure 1b. Wheat price differential

[4] In a recent study, Ahking tested the validity of the purchasing power parity (PPP) principle between U.S. and U.K. by using cointegration. In commenting on the difference between the unrestricted and restricted version of the cointegration regression Ahking (p. 913) states: "It should be noted that cointegration of exchange rate and prices is necessary but not sufficient condition for long-run PPP. Long-run PPP further requires a unit cointegrating vector." So, the proposition reported in the appendix can be viewed as giving sufficient conditions regarding the validity of the LOP as a long-run relationship.

[5] For example, consider the term structure of the interest rate. The cointegration parameter of the short- and long-term interest rate equals one, as implied by the expectations theory (Campbell and Shiller). Corbae and Ouliaris have used the theoretical restriction to test the purchasing power parity. Other studies of a similar nature include Hall and Ambler.

[6] The OLS estimate of β from (1) is biased even asymptotically (Stock). Banerjee et al. have shown through Monte Carlo experiments that the bias can be of substantial magnitude sometimes.

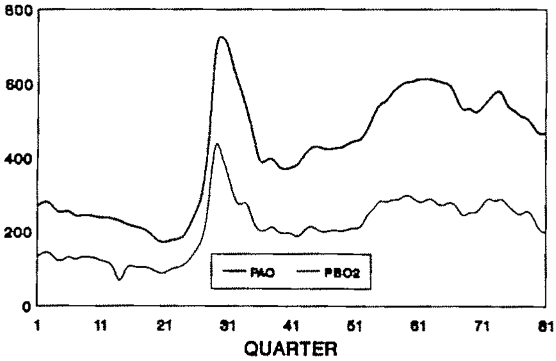


Figure 2a. Wool price in Australia and the U.K.

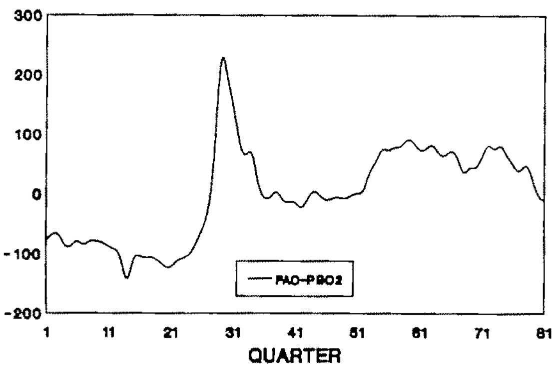


Figure 2b. Wool price differential

Determining the Order of Integration

To determine the sensitivity of the results with respect to stationarity properties, the following three procedures were employed: (*a*) Dickey-Fuller (DF), (*b*) augmented Dickey-Fuller (ADF), and (*c*) Durbin-Watson (DW). The DF test is based on the regression; $\Delta z_t = \mu + \beta z_{t-1} + \varepsilon_t$, where z_t denotes the variable being tested and Δ denotes the difference operator (i.e., $\Delta z_t = z_t - z_{t-1}$); μ and β are parameters to be estimated. The hypothesis tested is

$$H_0: z_t \text{ is not } I(0) \text{ against } H_1: z_t \text{ is } I(0).$$

H_0 is rejected if the estimate of β is negative and significantly different from zero. The ADF test accounts for the possibility tht ε_t is not white noise and is based on the regression: $\Delta z_t = \mu + \beta z_{t-1} + \Sigma_{i=1}^{\tau}\gamma_i \Delta z_{t-i} + \varepsilon_t$, where τ is selected so that ε_t is white noise; μ, β, and γ_i's are parameters to be estimated as before. Again, H_0 is rejected if β is negative and significantly different from zero. Finally, the DW test is based on the Durbin-Watson statistic of: $z_t = \mu + \varepsilon_t$. Low Durbin-Watson statistic indicates that z_t is not $I(0)$.

If H_0 is not rejected, we take first differences and repeat the same tests. In this case, the hypothesis becomes

$$H_0: z_t \text{ is not } I(1) \text{ against } H_1: z_t \text{ is } I(1).$$

Theoretically, this procedure is continued until H_0 is rejected in which case H_1 determines the order of integration. In practice, however, the procedure is terminated in first (and sometimes in second) differences because most economic variables are $I(1)$ and rarely $I(2)$.

Recently, several other procedures, which test for cointegration and impose less restrictions on the stochastic behavior of the error term of the cointegration regression, have been proposed (e.g., Perron; Phillips and Ouliaris). However, because the main purpose of this study is to test the LOP given the unitary restriction, these procedures were not applied.

Empirical Results

This section discusses empirical results which are in accordance with the testing procedure outlined above. The LOP was tested for the following commodities: wheat, tea, beef, sugar, wool, zinc, and tin, and countries: United States, Canada, Australia, and United Kingdom. The number of observations ranges from 71 to 118, representing quarterly average prices reported in the International Monetary Fund (*International Financial Statistics*). Because the data sets are identical, further details regarding the data and definitions of the variables can be found in Ardeni.

The first step regarding empirical analysis is the determination of the order of integration of prices. First, the levels of the prices were considered. Table 1 reports results for all three tests. The hypothesis that prices are not $I(0)$ was not rejected. All tests supported this conclusion, with the single exception of the *PBZ* and *PUZ* cases, for which the null hypothesis was rejected at the 10% level of significance (ADF test only). Second, first differences of the prices were considered. Results regarding stationarity tests for first differences are reported in table 2 and uniformly indicate that all prices are $I(1)$ (1% level of significance). To summarize, results from tables 1 and 2 show that the LOP for the specific commodities and time periods considered should be

Table 1. Stationarity Tests for Prices—Levels

Variable	Number of Observations	DF	ADF	DW
P_{AW1}	84	−1.54	−1.81	0.082
P_{AW1}	71	−0.41	−0.98	0.061
P_{AW2}	117	−1.45	−2.18	0.062
P_{AW2}	71	−1.43	−2.36	0.088
P_{UW}	71	−1.05	−1.73	0.057
P_{UW}	84	−1.52	−1.67	0.081
P_{UW}	117	−1.33	−1.46	0.060
P_{CW}	71	−1.38	−1.88	0.095
P_{BT}	84	−1.06	−1.26	0.173
P_{UT}	84	−0.70	−0.02	0.112
P_{AB}	89	−1.56	−1.49	0.064
P_{UB}	89	−1.29	−1.25	0.045
P_{AS}	80	−1.97	−1.97	0.160
P_{BS}	118	−1.39	−1.85	0.083
P_{BS}	80	−1.58	−2.00	0.116
P_{US}	118	−2.07	−2.47	0.149
P_{US}	80	−2.16	−2.01	0.205
P_{AO}	81	−1.38	−1.68	0.087
P_{BO1}	81	−1.05	−2.02	0.048
P_{BO2}	81	−1.42	−2.15	0.079
P_{BZ}	80	−1.88	−2.82*	0.153
P_{BZ}	89	−1.19	−1.57	0.030
P_{CZ}	80	−0.96	−1.22	0.026
P_{UZ}	89	−1.99	−2.72*	0.148
P_{UZ}	80	−0.99	−1.29	0.033
P_{BN}	83	−0.90	−0.93	0.030
P_{UN}	83	−0.82	−0.88	0.028

Notes: The first subscript identifies country: A is Australia; U, U.S.; C, Canada; and B, U.K. The second subscript identifies commodity: W is wheat; T, tea; B, beef; S, sugar; O, wool; Z, zinc; and N, tin. The numbers 1 and 2 following wheat for Australia and wool for U.K. indicate two different measures of prices.

A star (*) indicates rejection of the null hypothesis at the 10% level of significance (the critical value is −2.58).

The lag length regarding the ADF test was determined by the Akaike information criterion allowing up to a length of four lags.

In order to be consistent with the cointegration tests and at the same time use as many observations as possible, stationarity tests for some prices were conducted using more than one set of observations. For example, for P_{AW2} and P_{UW} there were 117 available observations, while for P_{CW} there were 71 observations only. For the stationarity tests of the pairs P_{AW2}–P_{CW} and P_{UW}–P_{CW}, we truncated P_{AW2} to 71. Hence, we tested for stationarity of P_{AW2} by using both 117 and 71 observations.

tested through cointegration as outlined in case (c) above.

Results regarding cointegration or alternatively stationarity of the price differential as defined in (2) are reported in table 3. In general, the results are favorable for the LOP. There is an agreement among all three tests as to the validity of the LOP. Considering the 5% level of significance, results can be summarized as follows: Out of a total of sixteen cases examined, the DF test does not reject the LOP in nine cases, the ADF test in ten cases, and the DW test in thirteen cases. In eight cases, all three tests indicate that the LOP cannot be rejected (5% level of significance). There is almost unanimous rejection of the LOP for wool [i.e., P_{AO}–P_{BO1} and P_{AO}–P_{BO2} are not $I(0)$] and in two of the wheat cases (P_{AW2}–P_{UW} and P_{AW2}–P_{CW}). Thus, rejection of the LOP is a price-specific problem rather than a general failure.[7]

Model Extensions

The primary focus of this section is to examine whether failure of the LOP for the P_{AW2}–P_{UW} and P_{AW2}–P_{CW} cases results from transportation costs. (The issue of transportation costs is discussed in Protopapadakis and Stoll 1983; Good-

[7] At this point one might ask why such differences between findings of this study and Ardeni's findings are present, given that the data set is identical and the testing procedures are similar. Ardeni considers the regression: $\ln(x_{1t}) = \alpha + \beta \ln(x^*_{2t}) + \varepsilon_t$ and tests for stationarity of ε_t, which upon rearranging terms becomes: $\varepsilon_t = \ln(x_{1t}/x^{*\beta}_{2t}) - \alpha$. The present study considers the difference: $z_t = (x_{1t} - x^*_{2t})$ and tests for stationarity of z_t; x_{1t} and x^*_{2t} denote levels of the prices. It is reasonable to expect that, even if z_t is $I(0)$, ε_t might not be $I(0)$ because of the nonlinear transformations performed upon x_{1t} and x^*_{2t}. Another reason for the differences in the findings is that the tabulated "t-values" utilized here are lower (in absolute terms) than the ones used in the cointegration regressions. This is the case because this study uses known cointegration parameters.

Table 2. Stationarity Tests for Prices—First Differences

Variable	Number of Observations	DF	ADF	DW
PAW1	84	−8.29	−5.28	1.854
PAW1	71	−4.48	−4.07	1.135
PAW2	117	−6.94	−4.42	1.195
PAW2	71	−5.06	−4.23	1.555
PUW	71	−4.67	−5.07	1.028
PUW	84	−8.23	−4.80	1.833
PUW	117	−9.79	−8.29	1.835
PCW	71	−7.34	−6.15	1.844
PBT	84	−8.36	−9.38	1.867
PUT	84	−8.06	−8.53	1.792
PAB	89	−9.18	−7.25	1.990
PUB	89	−8.58	−7.08	1.863
PAS	80	−9.39	−5.81	2.145
PBS	118	−8.47	−6.92	1.545
PBS	80	−6.92	−5.63	1.546
PUS	118	−7.76	−6.38	1.382
PUS	80	−6.23	−6.26	1.354
PAO	81	−7.03	−4.31	1.579
PBO1	81	−5.57	−4.36	1.171
PBO2	81	−5.32	−4.68	1.091
PBZ	80	−6.24	−5.45	1.364
PBZ	89	−5.54	−5.51	1.088
PCZ	80	−5.90	−4.71	1.332
PUZ	89	−6.72	−5.36	1.383
PUZ	80	−6.20	−4.71	1.376
PBN	83	−7.05	−6.72	1.538
PUN	83	−6.81	−6.47	1.472

Notes: for definitions of the variables see table 1.

The null hypothesis that the prices are not $I(1)$ is rejected for all prices at the 1% level of significance (significance levels and the corresponding critical values are reported in table 3).

Table 3. Cointegration Tests between Prices

Variable	Number of Observations	DF	ADF	DW
PAW1–PUW	84	−4.62***	−4.85***	0.844***
PAW1–PCW	71	−3.88***	−3.35**	1.033***
PAW2–PUW	117	−1.28	−2.00	0.094
PAW2–PCW	71	−1.82	−2.22	0.240
PUW–PCW	71	−3.45**	−3.82***	0.635**
PBT–PUT	84	−3.80***	−3.35**	0.594***
PAB–PUB	89	−3.18**	−2.76*	0.393***
PAS–PBS	80	−3.60***	−3.12**	0.614***
PAS–PUS	80	−3.21**	−2.91**	0.485***
PBS–PUS	118	−4.40***	−4.85***	0.574***
PAO–PBO1	81	−2.42	−1.89	0.282**
PAO–PBO2	81	−2.08	−2.23	0.190
PBZ–PCZ	80	−2.70*	−3.70***	0.361**
PBZ–PUZ	89	−2.63*	−3.91***	0.307**
PCZ–PUZ	80	−2.74*	−2.84*	0.367**
PBN–PUN	83	−6.24***	−3.66***	1.306***

Notes: Critical values for the DF and ADF tests (Fuller, $\hat{\tau}_\mu$ statistic, table 8.5.2) are:
100 observations: −3.51 (1%), −2.89 (5%), −2.58 (10%)
50 observations: −3.58 (1%), −2.93 (5%), −2.60 (10%)
Critical values for the DW tests (Sargan and Bhargava, table 1) are:
101 observations: 0.376 (1%), 0.259 (5%)
51 observations: 0.705 (1%), 0.493 (5%)

One asterisk indicates rejection at the 10% level; two asterisks indicate rejection at the 5% level; three asterisks indicate rejection at the 1% level.

Caution should be exercised when applying the DW test because the critical values are very sensitive to sample size.

For definitions of the variables see table 1.

win, Grennes, and Wohlgenant, among others.) For that issue to be investigated, freight rates were tested with respect to being cointegrated with the price differential. Because Australia, Canada, and The United States are net exporters of wheat, freight rates regarding the destinations Canada–Australia and U.S.–Australia were not available.[8] Instead, freight rates for the destinations St. Lawrence, Canada–U.K., North Pacific–U.K., U.S. Gulf–U.K., and West Australia–U.K. denoted as T_{CB}, T_{PB}, T_{GB}, and T_{AB}, respectively, were used. They represent quarterly averages reported in the International Wheat Council (*World Wheat Statistics*) and cover the 1957:1–1985:4 time period.

Because stationarity properties of freight rates are of interest in their own right, the order of integration of freight rates was determined for all four destinations and two sample sizes. Results are reported in table 4. The freight rate series between Gulf ports and U.K. (T_{GB}) is $I(0)$ at the 5% level of significance, as all three tests indicate. For the freight rates concerning Canada–U.K. (T_{CB}) and North Pacific–U.K. (T_{PB}), on the other hand, there is a disagreement among the three tests. The general conclusion, however, is that except of T_{CB}, the hypothesis that freight rates are not $I(0)$ is not uniformly rejected as occurred with the prices (compare with tables 1 and 2).

A second important result is the sensitivity of stationarity properties with respect to the time period examined. When we tested for stationarity using 68 observations, (essentially the second half of the sample size) instead of 112 as was the case before, all freight rates were found to be $I(1)$. That result points to the conclusion that the order of integration of freight rates depends on the time period considered.

To see whether transportation costs cause failure of the LOP, we tested for cointegration between freight rates and the price differentials P_{AW2}–P_{UW} and P_{AW2}–P_{CW}. Because the freight rates considered here are unlikely to coincide with the difference in the prices which is due to transportation costs, we tested for cointegration without restricting the cointegration parameter to one.[9] The results (table 5) showed weak evidence of cointegration. Specifically: while the DF test rejects cointegration (all t-values are less than -3.03, the 10% level of significance tabulated value), the ADF test indicates that cointegration exists in three cases at the 10% and one case at the 5% level of significance. With respect to the

[8] As one reviewer suggested, a way to overcome the problem of not having data on transportation costs between Canada and Australia is to take a ratio such as that of Australia-Japan and Canada-Japan freight charges. Tests (not reported here) between this ratio and the associated price differential showed no cointegration.

[9] We also tested for stationarity of the difference between freight rates and price differential. However, no evidence of cointegration was found.

Table 4. Stationarity Tests for Freight Rates

Variable	Number of Observations	DF	ADF	DW
Levels				
T_{AB}	112	−1.40	−1.95	0.084
T_{PB}	112	−3.45**	−2.51	0.313**
T_{CB}	112	−2.99**	−2.72*	0.252
T_{GB}	112	−3.34**	−3.31**	0.315**
T_{AB}	68	−1.49	−2.33	0.097
T_{PB}	68	−2.11	−1.82	0.292
T_{CB}	68	−2.07	−2.08	0.250
T_{GB}	68	−2.19	−2.66	0.271
Differences				
T_{AB}	112	−7.85	−6.05	1.129
T_{PB}	112	−11.85	−8.11	1.955
T_{CB}	112	−10.64	−6.47	1.893
T_{AB}	68	−5.39	−3.98	1.249
T_{PB}	68	−9.22	−4.83	2.282
T_{CB}	68	−8.11	−4.42	2.028
T_{GB}	68	−8.48	−4.16	2.103

Notes: The first subscript identifies source and the second destination: A is West Australia; P, North Pacific; C, St. Lawrence, Canada; G, U.S. Gulf Ports; B, U.K.).

Levels of significance are given in table 3. For the differences the null hypothesis that freight rates are not $I(1)$ is rejected at the 1% level of significance for all cases and all tests. Because T_{GB} (112 observations) is $I(0)$ we did not test for stationarity of the first difference.

Table 5. Cointegration Tests between Freight Rates and Price Differentials

Variables	Number of Observations	DF	ADF	DW
TAB, (*PAW2–PUW*)	112	−1.37	−2.11	0.110
TPB, (*PAW2–PUW*)	112	−1.44	−3.08*	0.105
TCB, (*PAW2–PUW*)	112	−1.66	−1.83	0.134
TAB, (*PAW2–PCW*)	68	−2.84	−3.25**	0.631
TPB, (*PAW2–PCW*)	68	−2.83	−2.40	0.630
TCB, (*PAW2–PCW*)	68	−2.85	−3.14*	0.637
TGB, (*PAW2–PCW*)	68	−2.84	−3.13*	0.642

Notes: Critical values for the cointegration tests (Engle and Granger, p. 269, table 2) are:
DF (100 obs.): −4.07 (1%), −3.37 (5%), −3.03 (10%)
ADF (100 obs.): −3.77 (1%), −3.17 (5%), −2.84 (10%)
DW (100 obs.): 0.511 (1%), 0.386 (5%), 0.322 (10%)
The critical values for DW, 50 observations (Engle and Yoo, p. 158, table 4) are 1.00 (1%), 0.78 (5%), and 0.69 (10%).

DW test, strong cointegration is found in four cases if we use the *t*-values corresponding to 100 observations, while no cointegration is found if the *t*-values corresponding to 50 observations are used. The sample consists of 68 observations.

To further investigate the link between transportation costs and failure of the LOP, the order of integration of freight rates as well as the price differential between *PAW2* and *PUW* were examined by considering only the first 62 observations (i.e., 1957:1–1972:2 period; note that results reported in tables 1 and 2 are based on the 1968:3–1986:1 period). Table 6 reports such results, which are in sharp contrast not only with respect to cointegration but also with respect to the order of integration of the individual price series. In particular, the null hypothesis that the price series are not $I(0)$ is not rejected at the 1% level as it was in the case before (table 1). Furthermore, when the price differential *PAW2–PUW* is considered, strong evidence of cointegration is found [given that the series are not $I(0)$]. Results regarding the order of integration of freight rates for the truncated sample strongly indicate that freight rates are $I(0)$.

To summarize, results from table 6 show that when freight rates are $I(0)$, the price differential is $I(0)$, which means that nonstationarity of freight rates may have been the main cause of nonstationarity of price differentials. Although this conclusion is not an outcome of a formal test, it does give additional evidence regarding the link between transportation costs and price differentials.

Explanations abound for the failure of the LOP even after taking into consideration transportation costs. For example, a nonstationary tax/subsidy might cause persistent divergence from long-run equilibrium. That may be the case if the tax/subsidy is exogenously determined, i.e., the explosiveness of the tax/subsidy is independent of the explosiveness of the price, hence the rejection of cointegration. Other reasons include heterogeneity of the data. For example, the prices examined may represent products of different quality, as might occur for wool.

Some important implications have emerged, especially with respect to international trade modeling. Consider the case of wheat. The fact that the differences *PAW1–PUW*, *PAW1–PCW*, and *PUW–PCW* are stationary implies that one would prefer *PAW1*, *PCW* or *PUW* over *PAW2*. This result is of particular importance because it directs researchers as to what price should be used and

Table 6. Stationarity Tests for Wheat and Freight Rates—Truncated Sample

Variable	Number of Observations	DF	ADF	DW
PAW2	62	−2.08	−3.19**	0.292
PUW	62	−3.21**	−2.83*	0.462
PAW2–PUW	62	−3.55**	−3.88***	0.599**
TAB	62	−5.14***	−3.08**	0.381
TPB	62	−7.01***	−4.66***	0.686**
TCB	62	−5.42***	−3.82***	0.520**
TGB	62	−5.56***	−3.22**	0.480

Notes: Levels of significance are given in table 3. The 62 observations of this test correspond to the 1957:1–1972:2 time period.

because it makes Isard's proposition (i.e., tests of the LOP would be insensitive to the particular selection of price) a testable hypothesis. Another implication is related to what commodities really can be modeled by assuming that a world price measure exists. For example, the results show that none of the wool prices can be used as a world price measure unless prices are decomposed and components which cause rejection of cointegration can be identified. On the other hand, for commodities such as sugar, the LOP assumption can be made rather safely. Finally, the simplicity of this test allows researchers to test the LOP rather than assume its existence before the price to be used is selected.

Concluding Comments

In this study the LOP was examined for seven commodities regarding four countries. The empirical results gave supportive evidence for the LOP for the specific commodities and time periods examined. In particular, the empirical results showed that (*a*) the failure of the LOP as a long-run relationship is a price-specific and time-period-specific problem rather than a general failure, and (*b*) a possible reason for the LOP failure is transportation costs. The results of this study are in agreement with recent studies (e.g., Officer; Protopapadakis and Stoll 1986; Goodwin, Grennes, and Wohlgenant; Goodwin 1990).

To further investigate the validity or denial of the LOP, a wider range of commodities must be examined. Furthermore, when the LOP does not hold, price decomposition could lead into the identification of the causes of the cointegration rejection and hence rejection of the LOP. Such issues await further research.

[Received November 1989; final revision received December 1990.]

References

Ahking, F. W. "Further Results on Long-Run Purchasing Power Parity in the 1920s." *Eur. Econ. Rev.* 34(1990):913–19.

Ambler, S. "Does Money Matter in Canada? Evidence from a Vector Error Correction Model." *Rev. Econ. and Statist.* 71(1989):651–58.

Ardeni, P. G. "Does the Law of One Price Really Hold for Commodity Prices?" *Amer. J. Agr. Econ.* 71(1989): 661–69.

Banerjee, A., J. J. Dolado, D. F. Hendry, and G. W. Smith. "Exploring Equilibrium Relationships in Econometrics through Static Models: Some Monte Carlo Evidence." *Oxford Bull. Econ. and Statist.* 48(1986):253–77.

Campbell, J. Y., and R. J. Shiller. "Cointegration and Tests of Present Value Models." *J. Polit. Econ.* 95 (1987):1061–88.

Coleman, M. "Cointegration-Based Tests of Daily Foreign Exchange Market Efficiency." *Econ. Letters* 32 (1990):53–59.

Corbae, D., and S. Ouliaris. "Cointegration and Tests of Purchasing Power Parity." *Rev. Econ. and Statist.* 70(1988):508–11.

Crouhy-Veyrac, L., M. Crouhy, and J. Melitz. "More About the Law of One Price." *Eur. Econ. Rev.* 18(1982):325–44.

Enders, W. "ARIMA and Cointegration Tests of PPP Under Fixed and Flexible Exchange Rate Regime." *Rev. Econ. and Statist.* 70(1988):504–7.

———. "Unit Roots and the Real Exchange Rate Before World War I: The Case of Britain and the USA." *J. Int. Money and Finan.* 8(1989):59–73.

Engle, R. F., and C. W. Granger. "Co-Integration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55(1987):251–76.

Engle, R. F., and B. S. Yoo. "Forecasting and Testing in Co-Integrated Systems." *J. Econometrics* 35(1987):143–59.

Fuller, W. A. *Introduction to Statistical Time Series*. New York: John Wiley & Sons, 1976.

Goodwin, B. K. "Empirically Testing the Law of One Price in an International Commodity Market: A Rational Expectations Application to the Natural Rubber Market." *Agr. Econ.* 4(1990):165–77.

Goodwin, B. K., T. Grennes, and M. K. Wohlgenant. "A Revised Test of the Law of One Price Using Rational Price Expectations." *Amer. J. Agr. Econ.* 72(1990):682–93.

———. "Testing the Law of One Price When Trade Takes Time." *J. Int. Money and Finan.* 5(1990):21–40.

Granger, C. W. "Developments in the Study of Cointegrated Economic Variables." *Oxford Bull. Econ. and Statist.* 48(1986):213–28.

———. "Some Properties of Time Series Data and Their Use in Econometric Model Specification." *J. Econometrics* 16(1981):121–30.

Hakkio, G.S., and M. Rush. "Market Efficiency and Cointegration: An Application to the Sterling and Deutschemark Exchange Markets." *J. Inter. Money and Finan.* 8(1989):75–88.

Hall, S. G. "An Application of the Granger & Engle Two-Step Estimation Procedure to United Kingdom Aggregate Wage Data." *Oxford Bull. Econ. and Statist.* 48(1986):229–40.

Hamilton, J. D., and M. A. Flavin. "On the Limitations of Government Borrowing. A Framework for Empirical Testing." *Amer. Econ. Rev.* 76(1986):808–19.

Hendry, D. F. "Econometric Modelling with Cointegrated Variables: An Overview." *Oxford Bull. Econ. and Statist.* 48(1986):201–12.

International Monetary Fund. *International Financial Statistics*. Selected issues.

International Wheat Council. *World Wheat Statistics*. Selected issues.

Isard, P. "How Far Can We Push the 'Law of One Price'?" *Amer. Econ. Rev.* 67(1977):942–48.

Officer, L. "The Law of One Price Cannot Be Rejected: Two Tests Based on Tradable/Nontradable Goods Dichotomy." *J. Macroecon.* 8(1986):159–82.

Perron, P. "The Great Crash, the Oil Price Shock and the Unit Root Hypothesis." *Econometrica* 57(1989):1361–1402.

Phillips, P. C. B., and S. Ouliaris. "Asymptotic Properties of Residual Based Tests for Cointegration." *Econometrica* 58(1990):165–93.

——. "Testing for Cointegration Using Principal Components Methods." *J. Econ. Dynamics and Control* 12(1988):205–30.

Protopapadakis, A. A., and H. R. Stoll. "Spot and Futures Prices and the Law of One Price." *J. Finan.* 38(1983):1431–55.

——. "The Law of One Price in International Commodity Markets: A Reformulation and Some Formal Tests." *J. Int. Money and Finance* 9(1986):335–60.

Richardson, J. D. "Some Empirical Evidence on Commodity Arbitrage and the Law of One Price." *J. Int. Econ.* 8(1978):341–51.

Sargan, J. D., and A. Bhargava. "Testing Residuals from Least Squares Regression for Being Generated by the Gaussian Random Walk." *Econometrica* 51(1983):153–74.

Stock, J. H. "Asymptotic Properties of Least Squares Estimators of Cointegrating Vectors." *Econometrica* 55(1987):1035–56.

Taylor, M. P., and P. C. McMahon. "Long-Run Purchasing Power Parity in the 1920s." *Eur. Econ. Rev.* 32(1988):179–97.

Appendix

PROPOSITION: *Let x_{1t} and x_{2t} denote the (nonstationary) prices of one commodity in countries 1 and 2. Further, let x_{2t}^* be the price in country 2 expressed in country 1's currency. Then, assuming that the LOP holds, testing for stationarity of the difference $x_{1t} - x_{2t}^*$ is a sufficient test for cointegration.*

Proof: Because of the LOP, x_{1t} and x_{2t} form a cointegrated system. Let $x_{1t} = ex_{2t} + \varepsilon_t$ be the cointegration regression where e represents the cointegration parameter. Under the LOP, e is the exchange rate (if it is constant) or the long-run counterpart of the exchange rate (if it is variable). The best (in the sense of least variance and unbiasedness) estimator of e, say $\hat{e}$, is the observed exchange rate. Expressing x_{2t} in terms of country 1's currency as $x_{2t}^* = \hat{e}x_{2t}$, and substituting it in the cointegration regression, yields: $x_{1t} = x_{2t}^* + \varepsilon_t$, which has a cointegration parameter of one. Thus, a stationarity test for ε_t is a sufficient test for cointegration. Q.E.D.

Results of a Price-Forecasting Competition: Comment

Abebayehu Tegene

In a recent article in this *Journal*, Dorfman and McIntosh presented the results of a price-forecasting competition in which three teams of econometricians were given 90 observations on seven variables and were asked to produce one-step-ahead, out-of-sample forecasts for observations 71–90 for two of the series (p_1, "feed" price, and p_2, "livestock" price). Also, the judges (Dorfman and McIntosh) tested out-of-sample forecasting performance, using the models to forecast values for additional observations. The last ten (91–100) observations were not provided to the teams. The three models chosen by the participants were the alternating conditional expectations (ACE) method, Bayesian vector autoregression (BVAR), and a bivariate state space (SS) model.

The forecasts were evaluated in terms of forecast accuracy and the ability to predict turning points. The measures that were used were mean-squared forecast error and the Henriksson-Merton test. Mean absolute percentage errors were also reported. Finally, a loss function defined as a convex combination of the mean-squared forecast error and the significance level from the Henriksson-Merton test was computed for each team's forecast for each series. The loss function was used to evaluate the relative performance of the three models.

This comment is concerned with the Henriksson-Merton test. The confidence levels of the Henriksson-Merton test as given in table 2 of Dorfman and McIntosh are in error. In almost all cases, the reported confidence levels exceed the actual levels. The errors in reported confidence levels also have affected the values of the loss function and, hence, the ranking of the models by the loss function criterion. In this comment, we provide the correct confidence levels of the Henriksson-Merton test for each of the three models and recompute the loss function using the correct confidence levels. We also present results from the Henriksson-Merton test in a regression framework suggested by Cumby and Modest.

The Henriksson-Merton test is a nonparametric test which focuses on direction rather than magnitude of changes. Calculation of this test provides information about the number of times each model correctly and incorrectly predicts both upward and downward directional changes in the variables of interest. For a series of N out-of-sample forecasts, define N_1 as number of observations where prices actually rose; N_2, number of observations where prices actually did not rise; $N = N_1 + N_2$, total number of out-of-sample observations; n_1, number of successful predictions given that price rose; n_2, number of unsuccessful predictions given that price did not rise; and $n = n_1 + n_2$, number of times a price rise was forecast. The Henriksson-Merton test for forecasting ability examines whether the observed number of successful predictions is unlikely under the null hypothesis of no forecasting ability. Henriksson and Merton show that the null hypothesis of no forecasting ability should be rejected if $n_1 \le x^*$, where x^* is the solution to

$$(1) \qquad \sum_{x=x^*}^{\bar{n}_1} \frac{\binom{N_1}{x}\binom{N_2}{n-x}}{\binom{N}{n}} = 1 - c,$$

where c is the confidence level and $\bar{n}_1 = \min(N_1, n)$.

The results are summarized in table 1. The table lists confidence levels for three forecast groupings: for all the thirty observations (71–100), for the first twenty observations (71–90), and for the last ten observations (91–100). As in Dorfman and McIntosh, the ACE model outperforms the other models in predicting directional changes in p_1 over all the three subsets of the data. Only the ACE model forecasts directional changes in p_1 for observations (71–100) and (71–90). When the last ten observations (the truly out-of-sample forecasts) are considered, none of the models show significant forecasting ability.

For p_2, the BVAR and SS models have identical confidence levels and perform better than the ACE model. The results indicate significant forecasting ability of both BVAR and SS models across all the forecasting horizons and for the ACE model for observations (71–100) and (71–90) at the 5% significance level. Note that when $n = N$, equation (1) is evaluated at $x = \min(N_1, n) = N_1$, and both the numerator and the denominator become unity. This implies that $c = 0$ for the confidence level. This occurs in the ACE model in the sample 91–100. That is, when a forecaster always forecasts up (or down), the

---

Abebayehu Tegene is an economist with the Resource and Technology Division of the Economic Research Service, U.S. Department of Agriculture.

The author thanks Fred Kuchler, LeRoy Hansen, and an anonymous *Journal* referee for comments on earlier drafts of this comment.

Table 1. Confidence Levels from Henriksson-Merton Tests

Model	c	n_1	n	N_1	N_2
Observations 71–100					
ACE1	.95244	9	13	14	15
ACE2	.99930	15	21	15	14
BVAR1	.73169	10	18	14	15
BVAR2	1.00000	14	15	15	14
SS1	.44998	10	20	14	15
SS2	1.00000	14	15	15	14
Observations 71–90					
ACE1	.94874	7	10	9	10
ACE2	.99988	10	11	10	9
BVAR1	.58593	5	9	9	10
BVAR2	.99989	9	9	10	9
SS1	.42998	6	12	9	10
SS2	.99989	9	9	10	9
Observation 91–100					
ACE1	.59524	2	3	4	5
ACE2	.00000	5	9	5	4
BVAR1	.44444	4	8	4	5
BVAR2	.95238	5	6	5	4
SS1	.16667	3	7	4	5
SS2	.95238	5	6	5	4

Note: ACE1 is the model for p_1, ACE2 is the model for p_2; BVAR1, BVAR2, SS1, and SS2 are similarly defined; c is the confidence level, n_1 is the number of successful predictions given that prices rose; n is the number of times (successful and unsuccessful) price rise was forecast; N_1 is the number of observations where prices actually rose; and N_2 is the number of observations where prices actually did not rise.

Henriksson-Merton test assigns a value of zero to the confidence level (see Henriksson and Merton, p. 524).

We computed the loss function

$$L = \alpha MSFE + (1 - \alpha)(1 - c), \tag{2}$$

where $MSFE$ is mean-squared forecast error, c is the confidence level, and $0 \leq \alpha \leq 1$. We used the $MSFE$ given in table 2 in Dorfman and McIntosh and c from our table 1. The loss function (2) was computed for each participant's forecast of each price series for three subsets of the data: for all thirty observations (71–100), the first twenty observations (71–90), and the last ten observations (91–100). To compare results with Dorfman and McIntosh, we evaluated the loss function for α values ranging from 0 to 1 at an increment of .01.

Over all thirty observations (71–100), the ACE model had the smallest loss for $\alpha \epsilon$ [0, .82], while the BVAR model had the smallest loss over the range $\alpha \epsilon$ [.83, 1] for p_1. The ACE model's performance in this subset of the sample is better than reported in Dorfman and McIntosh. The ACE model also had the smallest loss over the first twenty observations (71–90) for all values of α.

In Dorfman and McIntosh the BVAR model was reported to have dominated the other models by having the smallest loss for all values of α for the last ten observations (91–100). However, this is not the case. The ACE model has the smallest loss for $\alpha \epsilon$ [0, .42], while the BVAR model has the smallest loss in the remaining range $\alpha \epsilon$ [.43, 1]. For values of $\alpha \epsilon$ [.88, 1] the SS model has smaller loss than the ACE model.

For series p_2, the SS model dominates having the smallest loss for all α values other than zero in all the three subsets of the data. For $\alpha = 0$, SS and BVAR are tied in all the three subsets. Unlike Dorfman and McIntosh, SS is not tied with the ACE model for any value of α here.

We computed the Henriksson-Merton test in a regression framework as an additional means of evaluating the forecasting ability of each model. Cumby and Modest reformulated the test and proposed a method to implement the test in a simpler and more intuitive regression framework. They also showed that the Henriksson-Merton test is equivalent to a likelihood ratio test.

To implement the test, let $q_t = 1$ if the forecast change in a particular series is nonnegative, and $q_t = 0$ otherwise. Henriksson and Merton have shown that a necessary and sufficient condition for a forecaster's prediction to have no value is that

$$Prob[q_t = 0 \mid Z_t < 0] + [q_t = 1 \mid Z_t \geq 0] = 1, \tag{3}$$

where Z_t represents the actual change in the variable. Therefore, a test of a forecaster's ability to predict a directional change is to determine whether or not equation (3) holds.

Table 2. Regression Tests for Out-of-Sample Forecast Evaluation

Model[a]	ACE	BVAR	SS
Observation 71–100	Slope coefficient	Slope coefficient	Slope coefficient
p_1	.737	.190	−.197
	(3.097)	(.676)	(−.666)
p_2	1.096	1.163	1.185
	(4.640)	(6.696)	(7.044)
χ^2 test slopes = 0	25.246*[b]	28.043*	30.885*
Observation 71–90			
p_1	.960	.1367	−.077
	(3.224)	(.360)	(−.197)
p_2	1.424	1.352	1.386
	(6.311)	(5.578)	(5.992)
χ^2 test slopes = 0	31.521*	18.544*	22.800*

Note: See the footnote to table 1 for model definitions.
[a] Figures in parentheses are t-statistics.
[b] Asterisk indicates significance at .05 level. Critical value for $\chi^2_{(2)} = 5.991$.

The test is based on the following regression:

$$Z_t = \gamma + \beta X_t + \epsilon_t, \tag{4}$$

where $X_t = 1$ if the forecast change for a series is nonnegative and $X_t = 0$ if the forecast change is negative. Under the null hypothesis that the forecasting model has no ability to predict directional changes, $\beta = 0$. If the model is able to forecast directional changes in the variable, then $\beta > 0$. Note that the test is two-tailed. The null hypothesis would be rejected for β significantly less than zero as well. Thus, "perverse" forecasts which are consistently wrong would also be found to have information value.

Table 2 presents the estimated slope coefficients from the regression test of forecasting ability along with the t-statistics. Tests are performed for each model for two of the three subsets of the data: All thirty observations (71–100) and the first twenty observations (71–90). The third subset was dropped because it has only ten observations. For each model, a joint test that the slope coefficients in both series p_1 and p_2 are zero was performed. The joint test is based on a chi-square distribution. These statistics are also presented in table 2.

The slope coefficients for BVAR and SS models over both forecasting horizons are not significantly different from zero for series p_1 indicating that these two models have no ability to forecast p_1. Only the ACE model, with significant slope coefficient in both forecasting horizons, forecasts directional changes in p_1. All three models have significant forecasting ability over both forecasting horizons for series p_2. These results are consistent with those obtained from using equation (1) above. The joint hypotheses that a model's forecast has no value for both p_1 and p_2 is rejected for all three models at the conventional level of significance.

[Received December 1990, final revision received January 1991.]

References

Cumby, R. E., and D. M. Modest. "Testing for Market Timing Ability: A Framework for Forecast Evaluation." *J. Finan. Econ.* 19(1987):169–90.

Dorfman, J. H., and C. S. McIntosh. "Results of a Price Forecasting Competition." *Amer. J. Agr. Econ.* 72(1990):804–8.

Henriksson, R. D., and R. C. Merton. "On Market Timing and Investment Performance II: Statistical Procedures for Evaluating Forecasting Skills." *J. Bus.* 54(1981):513–33.

Results of a Price-Forecasting Competition: Reply

Jeffrey H. Dorfman and Christopher S. McIntosh

Tegene is correct in his "Comment" that the Henriksson-Merton confidence levels reported in our original results were in error. A "-1" missing from a single line of code led to inflated confidence levels. Unfortunately, our programming error was not discovered until after the galleys had been returned. We did not submit an erratum because the results of the competition did not change significantly.

The confidence levels reported by Tegene are indeed the correct ones. In fact, we helped him to understand the procedure used to calculate the Henriksson-Merton test and offered him our (corrected) program to aid his calculations.

Therefore, let us leave the original paper behind and move on to two new topics. First, Tegene proposes a "simpler" method of calculating the Henriksson-Merton test using a regression model which was developed by Cumby and Modest. We believe this test to have several drawbacks, and considerable caution needs to be applied when employing this form of the test. Second, because Tegene uses Cumby and Modest's regression framework to perform joint tests on both series included in the original competition, we present some results using the original Henriksson-Merton framework on both series.

Cumby and Modest are interested in developing tests with different underlying assumptions which they feel are better suited to their application: trying to decide which investment advisor has the best forecasts for the rates of return of several potential investments. In particular, they worry about Henriksson and Merton's assumption that the forecasts are independent of the magnitude of the difference in the rates of return. However, in our application, rather than trying to forecast which of two investments will have a higher rate of return, the competitors were trying to forecast the values of two price series. Point forecasts were provided and the direction of revision forecasts, i.e., the sign of $\hat{y}_t - y_{t-1}$, were constructed from the point forecasts. The competitors did not provide one set of point estimates and another set of up/down forecasts. Therefore, it seems reasonable to maintain the assumption that the forecasts of the direction of revision are independent of the subsequent magnitude of the change in the series.

Further, the particular test performed by Tegene is not equivalent to the Henriksson-Merton test performed in Dorfman and McIntosh. Cumby and Modest present three possible modifications of the Henriksson-Merton procedure, two of which maintain the independence assumption discussed above and one which does not. Tegene performs the test which does not impose the independence restriction. This allows a forecast to have information value if it helps predict both the sign and the magnitude of the change in the series. This measure of information value makes sense in the stock market, where if you win big once in a while and lose small most of the time you can make money. However, that was not the criterion by which we had promised to judge the competitors. The competitors were informed in advance of the criteria for the competition, and it would not have been fair to evaluate them by a different standard.

Another difference between the two procedures is that all three of the Cumby and Modest tests depend on an arbitrary choice of functional form and an assumption on the distribution(s) of the error terms. This leads these tests to have only asymptotic properties (conditional on the functional form). In contrast, the original Henriksson-Merton test is nonparametric and exact in finite samples. In fact, Cumby and Modest admit that the Henriksson-Merton test is a Fisher exact test, making it a uniformly most powerful unbiased test of the hypothesis in question. Because of the finite sample properties, and because the independence assumption seems a reasonable tradeoff for maintaining the nonparametric nature of the test, we continue to prefer the Henriksson-Merton test to the Cumby and Modest modified versions.

Last, let us consider joint tests for information value. Tegene used a likelihood ratio test to test the joint hypothesis of information value in a competitor's forecasts for both series. The original Henriksson-Merton test allows a joint hypothesis to be tested without any modification: just perform the same counting routines outlined by Tegene and calculate the test statistic. We calculated Henriksson-Merton confidence levels for the joint forecasts of each of the three competitors using the original Henriksson-Merton framework. These values (*JHMc*) are reported in table 1. Also in table 1 are the summed, normalized mean-squared forecast errors (*NJMSFE*s) for the two series. This is simply the sum of the *MSFE* for each competitor's forecasts of each series divided by the variance of the actual series, $NJMSFE = MSFE_1/\text{var}(p_1) + MSFE_2/\text{var}(p_2)$. This normalization allows the *MSFE*s to be added with logical consistency. The *NJMSFE*s can be combined with the joint Henriksson-Merton confidence levels to allow the same type of loss function calculations we performed in "Results." That is, $L(\alpha) = \alpha NJMSFE +$

Jeffrey H. Dorfman and Christopher S. McIntosh are assistant professors in the Department of Agricultural and Applied Economics, University of Georgia.

Table 1. Normalized Joint *MSFE*s and Henriksson-Merton Confidence Levels

	NJMSFE[a]			*JHMc*[b]		
Observation Numbers	ACE[c]	BVAR[c]	SS[c]	ACE	BVAR	SS
71–100	2.144	1.310	1.255	.99979	.99993	.99947
71–90	1.166	1.363	1.299	.99998	.99854	.99593
91–100	9.933	1.397	1.402	.69005	.95882	.85294

[a] The sum of the mean-squared forecast errors on each of the two price series, both normalized by the variance of the series.
[b] The confidence level for rejecting a null hypothesis of no information value in the forecasts of both price series.
[c] ACE represents the forecasts produced by Berck and Chalfant, BVAR the forecasts produced by Bessler, and SS the forecasts of Criddle and Havenner. For more details see their papers from the original competition.

Table 2. Minimum Loss Forecasts

	Price 1			Price 2			Joint		
Observation Numbers	ACE	BVAR	SS	ACE	BVAR	SS	ACE	BVAR	SS
71–100	[0, .82][a]	[.83, 1]			[0]	[0, 1]		[1]	[0, .99]
71–90	[0, 1]				[0]	[0, 1]	[0, 1]		
91–100	[0, .42]	[.43, 1]			[0]	[0, 1]		[0, 1]	

[a] The values in the table are the range of α for which each model has minimum loss for $L(\alpha) = \alpha MSFE + (1 - \alpha)(1 - HMc)$.

$(1 - \alpha)(1 - JHMc)$. We use $(1 - JHMc)$, the joint significance level, because we want small to be preferred. This loss function was calculated for values of α ranging from 0 to 1, at intervals of 0.01, and for all three subsets of the data (71–100, 71–90, 91–100). The range over which each of the three competitor's models achieved minimum loss is reported in table 2, along with the corrected ranges for each of the two series, individually.

The results of this joint evaluation are that each competitor performs the best on one of the three subsets. The ACE model of Berck and Chalfant dominates the forty observable out-of-sample forecasts, the state space model of Criddle and Havenner has the minimum loss for the entire sixty forecasts, and the BVAR model of Bessler outperforms the other two on the final twenty, unobservable, observations. It is worth noting that the confidence levels for the joint Henriksson-Merton test do not match the confidence levels implied by the chi-square tests performed by Tegene. In fact, all six of the chi-square tests done (Tegene excluded the 91–100 subset) have implicit confidence levels exceeding 0.9999, while the Henriksson-Merton test produces only two confidence levels of that magnitude for those six sets of forecasts. Thus, the asymptotic test used by Tegene appears to overestimate the information value of the forecasts. This is a common feature of asymptotic tests and provides another basis for favoring the Henriksson-Merton procedure.

In conclusion, the original Henriksson-Merton test procedure for value of information works in both univariate and multivariate cases. The original Henriksson-Merton test is nonparametric and exact in finite samples, while the Cumby-Modest procedure relies on a distributional assumption and on appeals to asymptotic theory. The regression framework of Cumby and Modest involves removing one assumption, but adding several others and should be employed with great care and assurance that the application really is the type of problem Cumby and Modest were trying to solve (which is a slightly different one than Henriksson and Merton solved).

[Received January 1991; no revision.]

References

Berck, P., and J. A. Chalfant. "Forecasts from a Nonparametric Approach: ACE." *Amer. J. Agr. Econ.* 72(1990):799–803.

Bessler, D. A. "Forecasting Multiple Time Series with Little Prior Information." *Amer. J. Agr. Econ.* 72(1990):788–92.

Criddle, K. R., and A. M. Havenner. "Forecasts from a State Space Multivariate Time-Series Model." *Amer. J. Agr. Econ.* 72(1990):793–98.

Cumby, R. E., and D. M. Modest. "Testing for Market Timing Ability: A Framework for Forecast Evaluation." *J. Finan. Econ.* 19(1987):169–89.

Dorfman, J. H., and C. S. McIntosh. "Results of a Price-Forecasting Competition." *Amer. J. Agr. Econ.* 72(1990):804–8.

Henriksson, R. D., and R. C. Merton. "On Market Timing and Investment Performance II: Statistical Procedures for Evaluating Forecasting Skills." *J. Bus.* 54 (1981):513–33.

Ex Ante Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin: Comment

Martin I. Meltzer

In the November, 1989, issue of the *AJAE*, Lemieux and Wohlgenant (LW) estimate changes in consumer and producer surpluses brought about by the introduction of a new biotechnology, porcine somatotropin (pST). The authors maintained that one of the main contributions of their paper is "to show how experimental research can be used to quantify shifts in the market supply curve" (p. 903).

While their methodology appears to be correct, the authors fail to fully appreciate the results and implications of the experimental research used in their analysis. It is argued that they overestimated the potential industry-wide average of pST-induced increases in production efficiency. This results in inflated estimates of both the reductions in marginal costs and the increases in producer surpluses. This paper will discuss these problems and conduct some sensitivity analyses on the relevant parameters.

Technology-Related Parameters

There are two important adoption-of-technology-related problems in LW's paper. These are (*a*) their assumption that pST will cause an average increase in feed efficiency of 24% regardless of the type of delivery system used, and (*b*) the lack of discussion concerning the level and type of management skills that will be required to maximize technical and economic returns to using pST.

First, the authors assumed that pST would be administered in a daily injection for fifty-nine days, with total injection-related labor costs of $0.57 per head.[1] Besides the question of practicality and the cost of labor, daily injections may cause additional problems, such as abscesses and stress, both of which would reduce production. The potential manufacturers of pST and other somatotropins are fully aware that they must produce a delivery system that is more practical than daily injections. To date, the two most promising delivery technologies appear to be (*a*) prolonged release injections, where intramuscular injections are given, say, every 14 days (Bauman et al.); and (*b*) a surgically placed, subcutaneous prolonged release implant (Knight et al. 1989, 1990).

Unfortunately, there is a trade-off between technical efficiency and the increased ease of delivery offered by less frequent injections or prolonged release implants. Because there is no way to fully regulate the absorption of the somatotropin once a prolonged release rejection or implant has been given, there is an uneven flow of the hormone to the animal's metabolic regulatory system. The net result is that the researchers have been unable to report absolutely consistent increases in feed efficiency, even when experiments are conducted under very similar situations. For example, Knight et al. (1989, 1990) reported increases in feed efficiency of 14.6% and 22.4%, respectively, in pST-treated hogs kept under thermoneutral conditions (18°–21° C). Even LW (p. 910) cite a paper that reports PST-induced gains in feed efficiency ranging from 13%–29% (delivery systems were not clarified).

Differences in gains in efficiency resulting from different delivery systems have been experienced in other species. Daily injections of bovine somatotropin (bST) have elicited an increase in milk yields of up to 30% (Bauman and McCutcheon, Bauman). However, prolonged release injections have caused milk yield increases of only 10%–15% (Bauman et al. 1989). In summary, to date there is no reason to believe that 24% is the sole representative coefficient for pST-induced gains in feed efficiency.

Also to be taken into consideration is the level of management capability required to make biotechnology products "work" (the second problem). Given a relatively cheap price ($6/hd; LW, p. 910), pST can be assumed to be scale neutral, but it is not management neutral (Meltzer, Meltzer and Kalter). The skills needed include the ability to accurately reformulate feed so that pST treated pigs have enough amino acids in their diet to allow for the maximum possible increase in protein accretion (Boyd and

---

Martin I. Meltzer is a veterinary economist, Department of Infectious Diseases, College of Veterinary Medicine, University of Florida.

This paper is published as Florida Agricultural Experiment Station Journal Series No. R-00784.

The author wishes to thank William Boggess, Robert Kalter, William Tomek, and several other colleagues for their helpful comments on earlier drafts.

[1] There is no indication in their article, nor in an earlier paper (Lemieux and Richardson), as to how this cost was calculated. However, in a paper that also discussed the potential impact of pST, Meisinger assumed that the labor for daily injections would cost $1.46 per head, "based on a producer's ability to inject 325 hogs per hour at a labor cost of $6.50/hr." Assuming the wage rate represents one laborer, Meisinger implies that, every day, that laborer would have to be capable of injecting one hog every eleven seconds! It is doubtful if a farmer could find two laborers, each willing to do the job for minimum wage ($3.25/hr). Because LW actually use a labor price that is about 40% of that used by Meisinger, the above calculations suggest that they imply an ability of injecting one hog every 5–6 seconds!

Krick). In the specific case of lysine, it has been estimated that "a 58–65% increase in lysine (35–36 g/d [grams per day]) would be required . . . in order to accommodate the response to somatotropin [in hogs]" (Boyd and Krick, p. 155). In the earlier referenced experiment by Knight et al. (1989), hogs given pST were fed a diet which contained 18% crude protein, 1.2% lysine and having 3.66 megacalories digestible energy per kilogram. In contrast, LW allowed the adoption of pST to change hog rations from 14% to 16% crude protein, with no mention of increasing the concentration of lysine.

There is empirical evidence that suggests that not all farmers have the managerial capabilities to formulate feeds with the precision required to maximize gains from pST. Based on profit and loss statements, Welsch et al. divided data from 168 hog farms in southwestern Minnesota into three groups; least efficient (bottom 20%), average efficient (60%) and the most efficient farms (top 20%). The data set demonstrated a strong correlation between economic efficiency (as defined by the net profit of each farm) and the technical efficiency (as defined by the feed efficiency). For example, compared to the most economically efficient farms, the least economically efficient farms fed an extra 2.8 bushels of corn (+24%), and an additional 97 pounds of supplement (+53%) per finished hog. Such disparities indicate that some farmers probably lack the managerial capabilities to "fine tune" the diets necessary to maximize the technical and economic gains from using pST.

This need to have certain management skills in order to maximize gains from pST can be analyzed from another point of view. That is, there is bound to be a process of adoption and learning among the hog-producing industry. Models of the diffusion of agricultural technology that allow for educational background have been presented (e.g., Kislev and Shchori-Bachrach). LW allow for this diffusion process when calculating the short-, intermediate-, and long-run impacts of pST [the α coefficient, eq. (22), LW, p. 911]. However, what LW did not discuss is the fact that, associated with the diffusion of a technology, there is an individual learning process each farmer must go through before he will make the best use of the technology. There have been instances where this can take considerable time. For example, the adoption and use of draft power in West Africa (Jaeger and Matlon). Thus, in LW's short-run, one-year scenario, the 22% of the farmers who are assumed to adopt the technology (the "innovators"?) may not achieve an average of 24% increase in feed efficiency within the first year of use.

Another element of the cycle of innovation is that the largest possible technical gains from using pST, at least initially, may not be the most economically efficient (i.e., may not ensure the largest net profits). The market price of hogs, and the premiums paid for lean carcasses, may not rapidly adjust to reflect the impact of pST upon the hog production. Thus, it might not be profitable for a farmer to increase protein concentration in the diets fed to pST-treated pigs to the extent suggested by the above research. In the case of a single producer, the economic efficiency of using pST could be researched by a basic model (e.g., a linear programming model, see Meltzer) which optimized net profit given a set of exogenously determined input and output prices. LW's linear elasticity model does not optimize directly, though the coefficients for the parameters can be obtained from optimization procedures (LW, p. 903).

A far more complex, intertemporal optimization model of the entire industry would allow direct incorporation of several of the management-based variables discussed above while optimizing farmer profits at each time step, given frequent changes in input and output prices. Such an optimization model would also allow farms to drop out of hog production as the price of hogs falls because of pST-induced increases in production, presenting a picture of how pST could restructure the entire industry. Work of this type has already been done for the dairy industry and the adoption of bST (Sellschopp, Sellschopp and Kalter). Although such a net profit optimization approach represents a somewhat different line of research than that used by LW, the theoretical concepts involved (e.g., innovation cycle, economic versus technical efficiency) give another set of reasons to question if one coefficient can adequately represent the entire spectrum of probable average increases in feed efficiency caused by pST.

The above discussion suggests that, without changing anything else in LW's model, it would be reasonable to conduct sensitivity analyses on the cost of administering pST, and/or the assumed, industry-wide average increases in feed efficiency. In the latter case, using the work of Knight et al. (1989, 1990) and Bauman et al. as a general guide and allowing for nonuniform management capabilities, it does not seem unreasonable to conduct sensitivity analyses using either a 10% or 15% pST-induced increase in feed efficiency. Combined with the 24% used by LW, the results would then represent the low, middle, and upper ranges of some of the industry wide impacts of pST.

Sensitivity Analysis: Change in Marginal Costs of Production

The first step in modeling the effect of different levels of pST-induced feed efficiency is to apply equation (22) in LW's paper (p. 911):

$$k = [-(1 + 1/\varepsilon)\delta - \varepsilon_f \theta^* + \text{injection costs}]\alpha,$$

where k is the net percentage change in marginal cost of hog production, ε is the short-run elasticity of supply, ε_f is the short-run elasticity of marginal cost, δ is the pST induced increase in production (liveweight), θ^* is the adjusted biased technical parameter (i.e., value of feed saved), and α is the per-

centage of farmers adopting pST. For the purposes of this sensitivity analysis, LW's short-run (1-year adjustment) and intermediate-run (5-year adjustment) situations will be used. Further, there will be two marketing-related scenarios within the short-run situation. The first assumes that the farmers will continue to sell hogs at the fixed market liveweight of 240 pounds (i.e., $\delta = 0$). Such a situation may occur if, at the initial introduction of pST, meat-packing companies continue to effectively penalize farmers for delivering heavy hogs (i.e., greater than 240 pounds). The second scenario, and the one used by LW, assumes that the farmers will keep the number of days on feed constant (59 days; LW, p. 910) and produce heavier hogs (i.e., $\delta > 0$). In the intermediate-run situation, it will be assumed that the meat-packing industry will allow pST-induced heavier, but leaner, hogs to be delivered without penalty (i.e., only the second marketing-related scenario is applicable).

To calculate the amount of feed saved by using pST, the total amount of feed fed was first reduced from the baseline case of 387 pounds (LW, p. 910) by 10% and 15%, respectively. Then, in order to ensure that there is enough protein available in the diets for a pig's metabolism to take full advantage of the nutrient repartitioning effect of pST (see above), the composition of the diets must be balanced to give a crude protein (CP) content of 16%, compared to the "standard" finishing ration containing 14% CP (LW, p. 910). As discussed earlier, some research has suggested that the CP should be increased to 18%, plus have the lysine concentration increased to 1.2% (e.g., Knight et al. 1989; Boyd and Krick). However, in order to maintain a basis for an easy and direct comparison with LW's results, the sensitivity analyses will assume that the CP will be increased to only 16%, with no increase in costs due to additional lysine application.

Assuming that the CP of corn is 8% and soybean supplement is 46%, the diets for the first marketing-related scenario (sell at fixed weight) are as follows: for a 10% increase in feed efficiency, 73 pounds of supplement and 275 pounds of corn; for a 15% increase in feed efficiency, 69 pounds of supplement and 259 pounds of corn. The baseline figures are 70 pounds of supplement and 317 pounds of corn. In the second scenario (days on feed constant), a 10% gain in feed efficiency combined with an estimated 7% increase in rate of daily gain (R. D. Boyd, Cornell University, personal communication) requires 80 pounds of supplement and 293 pounds of corn. This will give a 7-pound heavier carcass (i.e., 247 lbs. liveweight, $\delta_{10\%} = 3\%$). With a 15% increase in feed efficiency and an estimated 10% increase in rate of daily gain (Boyd, personal communication), 76 pounds of supplement and 285 pounds of corn will be fed. This diet will produce a hog that is 10 pounds heavier (i.e., $\delta_{15\%} = 4\%$).

According to LW (p. 910), these estimates of feed fed can be used to calculate Θ^* (the value of feed saved). The authors assumed that the cost shares for corn and supplement were 0.54 and 0.46, respectively, and that 50% of all feed costs occur in the finishing stages when pST would be administered (LW, p. 910). Injection or implant costs were kept at 5.3% of the market value of the hog (LW, p. 911). Table 1 presents the various estimates of the value of feed saved (Θ^*), and the changes in marginal costs (k). Note that, in all scenarios, the values of k for the 10% and 15% gains in feed efficiency are less than half of those estimted by LW. The impact of assuming a lower gain in feed efficiency is highlighted by observing that, although the estimates of Θ^* in scenario 1 (short-run) show savings in feed fed (i.e., $\Theta^* > 0$), there are increases in the marginal costs of production (i.e., $k > 0$). This occurs because of the relatively high injection or implant costs and the fact that the farmers still sell at constant weight (i.e., $\delta = 0$).

Also note that, in scenario two (short run), a 10% increase in feed efficiency results in an increase in the farmers feed bill (i.e., $\Theta^*_{10\%} = -0.5\%$). The reason for this is that the cost of the extra 10 pounds of supplement needed to boost the diet to a 16% CP content is greater than the savings from the reduction in the amount of corn fed. However, this small increase in feed costs is negated by the extra revenue from selling a heavier hog ($\delta_{10\%} = 3\%$), resulting in a small decrease in total marginal costs ($k_{10\%} = -4.8\ \alpha$, where α = the adoption rate).

Sensitivity Analysis: Percentage Change in Producers Surplus

The different values of k (table 1) can be used to calculate the impact of pST on producers surplus, which is calculated as a percentage of total value of hog production [LW, eq. (20), p. 908]:

$$\frac{\Delta PS}{P_{HF}Q_{HFS}} = (EP_{HF} - k)(1 + 0.5\ EQ_{HFS}),$$

where PS is the producer surplus, and EP_{HF} and EQ_{HFS} are the expected changes in hog prices and hog production, respectively. Estimates of the latter two parameters were taken from LW (table 5, p. 912).

Table 2 presents the results of the changes in producer surplus, using the two scenarios for k (sell-at-constant-weight, constant-days-on-feed), short-run and intermediate-run time situations, different levels of technology adoption, and pessimistic and optimistic shifts in consumer demand (LW, p. 911). In all, there are thirty-two individual scenarios, of which twenty-four are the result of this sensitivity analysis.

Compared to the 24% increase in feed efficiency used by LW, lower pST-induced gains in feed efficiency result in a large number of cases where there are reductions in producer surplus. Among the twenty-four scenarios representing the smaller increases in feed efficiency, the only consistently positive gains in producer surplus occur in the short-run scenario 2,

Table 1. Percentage Changes in the Marginal Costs of Hog Production (k) Resulting from pST Use

Gain in Feed Efficiency (θ^* = value of feed saved δ = increase in liveweight)	Percent Changes in Marginal Costs (k) at Various Adoption Rates (α)	
Short Run		
Scenario 1 (sell at constant weight)	α = .22	α = 1.0
10% (θ^*=2.5%,δ=0%)	0.75	3.4
15% (θ^*=5%,δ=0%)	0.34	1.5
LW	Not applicable[b]	
Scenario 2 (days on feed constant)	α = .22	α = 1.0
10% (θ^*=−0.5%,δ=3%)	−1.06	−4.8
15% (θ^*=0.5%,δ=4%)	−2	−9.1
LW (θ^*=2.6%,δ=6.3%)	−4.18	−19
Intermediate Run		
Scenario 2 (days on feed constant)	α = .6	α = 1.0
10% (θ^*=−0.5%,δ=3%)	−2.8	−4.8
15% (θ^*=0.5%,δ=4%)	−5.5	−9.1
LW (θ^*=2.6%,δ=6.3%)	−11.4	−19

[a] θ^* is value of food saved; δ is increase in liveweight.
[b] LW did not consider the possibility of selling at constant weight.

which assumes a minimum of 15% increase in feed efficiency plus being able to sell a heavier hog ($\delta_{15\%}$ = 4%). In the intermediate run, assuming a pST-induced gain in feed efficiency of only 10% or 15% results in estimates of producer surplus that are all negative.

Discussion

By assuming that pST may be mass marketed with a delivery system other than daily injections and taking into account the wide range of managerial skills among existing hog farmers (Welsch et al.), it seems reasonable to assume that the average pST-related increase in feed efficiency may be lower than the 24% used by LW. In essence, they treat changes in the marginal costs of hog production (k) as known or fixed rather than as a rough estimate "requiring" sensitivity analysis. Using LW's model but taking 10% or 15% as alternative values for pST-induced increases in feed efficiency resulted in noticeably smaller estimates of the percentage change in (k) than those calculated by LW (table 1). These smaller estimates of (k) often result in losses in producer surplus rather than the gains predicted by LW (table 2). This indicates that the effects of a new technology on producer surplus is quite sensitive to changes in the parameters representing the physical impact of the technology itself, as well as the other factors which are discussed by LW (e.g., adoption rate, length of adjustment, change in demand, p. 912).

Tables 1 and 2 further suggest that it may be a useful exercise to use profit-maximizing optimization models to evaluate the adoption of pST at both the level of the individual farmer and the entire hog-producing industry. The latter model should allow for a restructuring of the industry. The reduction in producer surplus shown in 18 of the 32 scenarios presented in table 2 implies a fall in the average price received per hog, and the least economically efficient farms could be the susceptible to any increased financial pressure. That is, they are the most vulnerable to being forced out of hog production as a result of the introduction of pST. It is important to note that such a restructuring of the industry is based not on the size of individual farms (as implied in Lemieux and Richardson), but on the economic and technical efficiency of the farmers. A size-related effect will take place only to the extent that management efficiency is correlated to the size of farm (i.e., if larger farms indicate better management capability). Finally, the results from this sensitivity analysis also suggest that, in order for the hog-producing industry to gain the most from pST, the meat-packing companies must allow the farmers to sell heavier, but leaner, hogs without penalty (scenario 2, table 1).

[Received June 1990; final revision received January 1991.]

Table 2. Expected Percentage Changes in Producer Surplus (as a Percentage Total Value of Hog Production) Resulting from pST Use

Percent Increase in Feed Efficiency	Variable Adoption Rate		100% Adoption Rate	
	Consumer Reaction[a]		Consumer Reaction	
	Pessimistic	Optimistic	Pessimistic	Optimistic
Short Run	22% Adoption Ceiling			
Scenario 1 (sell at constant weight)				
10	−2.6	−1.3	−12	−6.2
15	−2.1	−0.8	−10.2	−4.3
24 (LW)		Not Applicable[b]		
Scenario 2 (days on feed constant)				
10	−0.7	0.6	−3.7	2.3
15	0.2	1.2	0.6	6.6
24 (LW)	2.4	4.4	10.8	16.9
Intermediate Run	60% Adoption Ceiling			
Scenario 2 (days on feed constant)				
10	−6.2	−4.5	−10.6	−7.6
15	−3.5	−1.7	−6.1	−3.1
24 (LW)	2.5	4.4	3.9	7.2

[a] See LW, p. 911, for definition of optimistic and pessimistic consumer reaction.
[b] LW did not consider the possibility of selling at constant weight.

References

Bauman, D. E. "Regulation of Nutrient Partitioning." *Herbivore Nutrition in the Subtropics and Tropics*, ed. F. M. C. Gilchrist and R. I. Machie, chap. 24, 1984.

Bauman, D. E., D. L. Hard, B. A. Crooker, M. S. Partridge, K. Garrick, L. D. Sandles, H. N. Erb, S. E. Franson, G. F. Hartnell, and R. L. Hintz. "Long Term Evaluation of a Prolonged-Release Formulation of N-Methionyl Bovine Somatotropin in Lactating Dairy Cows." *J. Dairy Sci.* 72(1989):642–51.

Bauman, D. E., and S. N. McCutcheon. "The Effects of Growth Hormone and Prolactin on Metabolism." *The Control of Digestion and Metabolism in Ruminants*, ed. R. M. Milligan, W. L. Grovum, and A. Dobson, chap. 23. Englewood Cliffs NJ: Prentice-Hall, 1986.

Boyd, R. D., and B. Krick. "Relationship Between Amino Acid Intake and Protein Accretion in Growing Swine Receiving Somatotropin." *Proceedings, Cornell Nutritional Conference*, pp. 149–61. Syracuse NY, Nov. 1989.

Jaeger, W., and P. Matlon. "Utilization, Profitability, and Adoption of Animal Draft Power in West Africa." *Amer. J. Agr. Econ.* 72(1990):35–48.

Kislev, Y., and N. Shchori-Bachrach. "The Process of an Innovation Cycle." *Amer. J. Agr. Econ.* 55(1973):28–37.

Knight, C. D., B. A. Becker, H. B. Hedrick, G. W. Jesse, and C. A. Baile. "The Effect of Heat on Performance and Carcass Responses of Finishing Hogs Treated with a Single PST Prolonged Release Implant (PST-I)." *J. Animal Sci.* 67(1989, supp. 1):213.

——. "The Effect of Heat upon Performance and Heat Production of Finishing Hogs Treated with a Single PST Prolonged Release Implant (PST-I)." *J. Animal Sci.* 68(1990, supp. 1):319.

Lemieux, C. M., and J. W. Richardson, "Economic Impacts of Porcine Somatotropin on Midwest Hog Producers." *N. Cent. J. Agr. Econ.* 11(1989):171–81.

Lemieux, C. M., and M. K. Wohlgenant. "*Ex-Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *Amer. J. Agr. Econ.* 71(1989):903–14.

Meisinger, D. J. "Potential Economic Impact of Carcass Modifiers." *J. Animal Sci.* 67(1989):2150–54.

Meltzer, M. I. "Repartitioning Agents in Livestock: Economic Impact of Porcine Growth Hormone." M.S. thesis, Cornell University, 1987.

Meltzer, M. I., and R. J. Kalter. "Porcine Growth Hormone: Implications for Hog Producers and the Swine Industry." Selected paper presented at AAEA annual meeting, East Lansing MI, 1987.

Sellschopp, J. "The Impact of Technical Change on the Spatial Distribution of Agriculture: Bovine Somatotropin and the U.S. Dairy Industry." Ph.D. thesis, Cornell University, 1989.

Sellschopp, J., and R. J. Kalter. "Bovine Somatotropin: Its Impact on the Spatial Distribution of the U.S. Dairy Industry." Dep. Agr. Econ. A.E. Res. No. 89-14, Cornell University, 1989.

Welsch, D. E., B. Keffe, E. J. Weiness, P. A. Fales, and D. E. Talley. "Southwestern Minnesota Farm Management Association: 1984 Annual Report." Dep. Agr. and Appl. Econ., Econ. Rep. No. ER 85-2, University of Minnesota, May 1985.

Ex Ante Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin: Reply

Catharine M. Lemieux and Michael K. Wohlgenant

Meltzer criticizes our paper primarily on the basis of the accuracy of the animal science assumptions. However, in attempting to demonstrate that our results are sensitive to the technology assumptions, he misapplies the formulas required to translate the experimental information into cost changes and surplus changes [eqs. (20) and (22), Lemieux and Wohlgenant]. The purposes of this reply are two-fold: first, to show that the animal science assumptions we employed in our analysis are defensible and plausible; second, to show that Meltzer misapplied our formulas in quantifying his revised estimates of the experimental effects of PST. The latter objective should also serve to clarify the application of our methodology in future studies concerned with new technology adoption such as PST.

Animal Science Assumptions

Meltzer states that we have assumed the same improvements in feed efficiency and average daily gain without regard to the type of delivery system that will be used. We clearly state (and Meltzer later acknowledges this) that we assume PST will be administered daily.

The benefits of daily PST have been reported numerous times in the animal science literature. Meltzer says the results concerning the impact of PST on animal growth are inconsistent. We can only agree. This is why we adopted the assumptions on improvements in feed efficiency and average daily gain that represent the average obtained from a total of nineteen studies. Meisinger reports this summary as well as the results of several additional studies that used daily administration of PST without additional lysine and reported benefits equal to or greater than our assumptions. Additionally, Hayenga et al. assumed a 25% improvement in feed efficiency and a 12% improvement in average daily gain in their analysis of the economic impact of PST.

It is not our purpose to second guess the various animal health companies that are working to develop this product for commercial use. The benefits Meltzer advocates using may be appropriate for a prototype sustained release system. It is entirely likely that over time the technology of sustained delivery will improve so that performance with this delivery system would be equal to daily administration. The economic model described in our article can be used to evaluate the economic benefits of a sustained release product as well as other growth regulators such as beta agonists.

Meltzer points out that this technology is not management neutral. We agree. What new technology is? However, the assumptions we have made concerning the impact of PST only require increasing the crude protein content of the diet from the standard 14% to 16%. It is true that adding lysine to the diet improves the results of PST. Goodband et al. at Kansas State University found improvements in feed efficiency of as much as 30% with added lysine.

Iowa State University has recently released the results of an on-farm evaluation of PST administered daily. This study was funded by the Iowa Department of Economic Development and conducted by Ken Prusa and Lauren Christian. Fifteen Iowa pork producers representing diverse operations treated a total of 1,343 animals. The top five producers achieved a 24% improvement in feed efficiency and the top ten producers achieved an 18% improvement in feed efficiency. These results indicate that daily administration of PST is "practical" and possible.

Meltzer points out that we have not estimated the most economically efficient feed formulation for a producer using PST. This is correct. We have only evaluated the economic impact of using PST administered daily on hogs fed a 16% crude protein diet. Our results show that daily treatment of PST with this diet can be profitable. We did not investigate whether additional diet supplementation would be more profitable. As more accurate information is available on the impact of PST under various diets and feed supplements, this work will be done.

Meltzer criticizes our assumption that packers will pay a premium for leaner hogs and that they will not discount heavy hogs. The current discount for heavy hogs is because heavier hogs are fatter. A 1988 University of Wisconsin survey of packers (Kauffman et al.) found that twelve out of thirteen of the packers surveyed, representing three-fourths of all hogs pur-

Catharine M. Lemieux is an adjunct associate professor of agricultural economics, Kansas State University; Michael K. Wohlgenant is a professor of agricultural and resource economics, North Carolina State University.

Without implication, appreciation is expressed by the authors to Kelly Zering for helpful comments.

chased in the United States, were already buying hogs on the basis of carcass merit, and all packers surveyed use a fat measurement. One of the benefits of PST is that it produces leaner hogs. Heavier PST-treated hogs will have backfat similar to today's 240-pound hogs, thus providing packers with more saleable product. This was the result obtained in Prusa and Christian's on-farm study.

Consumers are willing to pay more for leaner cuts of pork. This premium will be transmitted to producers as packers bid more for leaner hogs. Work we presented at the AAEA meetings in 1988 showed that consumers are willing to pay an average of between 6¢ and 22¢ per pound for leaner pork. The National Pork Producers Council is supporting this trend toward lean value pricing with their Pork Value Program, and other economic work is being sponsored to analyze the effectiveness of various methods of measuring backfat in live animals. Meltzer's assumption that producers market their hogs at a constant weight implies that producers will let their facilities remain idle a portion of the year because it takes less time for each treated animal to reach market weight.

Meltzer criticizes the values used for labor charges for PST treatment used by Lemieux and Richardson. We are surprised that it is necessary to defend calculations used in a different model, published by different authors, in a different journal. The Lemieux and Richardson paper used FLIPSIM, a deterministic model, and the purpose of the research was to estimate the impact of PST on individual producers. The model assumed that the three sizes of family farms modeled were able to provide some family labor to perform PST treatment. Because the charge for family labor does not increase with the adoption of PST, the added cost of using family labor to administer PST is negligible. Meisinger states that 325 hogs could be injected in one hour. Because he has done it and we know of no other source on this subject, this estimate was used in the Lemieux and Richardson paper. For clarification, it should be noted that treatment in this context does not require that an animal be restrained or removed from its pen.

Methodology

The major errors made by Meltzer are in applying our formulas to estimate alternative changes in marginal cost and changes in economic surplus. With respect to calculating changes in marginal costs of production, Meltzer misapplies our equation (22) in his scenario 1 when he sets $\delta = 0$ to characterize farmers continuing to market hogs at 240 pounds liveweight. By setting $\delta = 0$, Meltzer ignores any benefits that the producer would gain through an improvement in average daily gain from the use of PST. Specifically, if the farmer decides to continue marketing hogs at the same liveweight, the time it takes to reach the same weight will be less as a result of the improvement in average daily gain from the technology. Less time to the same weight translates into cost savings on feed and other variable costs. It turns out that, for reasonable estimates of improvement in feed efficiency and average daily gain, the bulk of the benefits to producers comes from an improvement in average daily gain.

To make this point forcefully, consider the situation confronting a typical firm as shown in figure 1. The firm is initially producing Q_0 pounds of pork where price P_0 equals marginal cost (MC). The effect of an improvement in average daily gain would be for marginal cost to shift from MC to MC'. At the original price P_0, the producer has an incentive to increase production from Q_0 to Q_1. This increase in production is equal to the amount $(1 + \epsilon)\ \delta \cdot Q_0$, where ϵ is the firm's own-price elasticity of supply. In general, this increase in output could be achieved through increasing the market liveweight of the existing number of hogs, increasing the number of hogs at the same market liveweight, or a combination of the two. However, even if the total quantity produced happened to remain constant at Q_0 the producer would still experience a benefit because of the change in marginal cost from MC to MC'. This change in marginal cost at Q_0 is equal to the amount $-(1 + \epsilon)\ \delta \cdot MC/\epsilon = -(1 + 1/\epsilon)\ \delta \cdot MC$. Thus, the percentage change in MC from improvement in average daily gain is $-(1 + 1/\epsilon)\ \delta$ [equation (4a) Lemieux and Wohlgenant]. Changes in marginal cost from feed input savings and the cost of injections would cause additional shifts in the marginal cost curve.

Assuming MC' represents the new marginal cost curve after injection with PST, the producer clearly has an incentive to increase production provided the new market price is above point A. If, in fact, industry-wide adoption occurred causing market price to fall to P_1, then the typical firm would expand production from Q_0 to Q_2. Again, this increased production could be achieved by increasing the market liveweight of the hogs, increasing the number of hogs marketed at the same liveweight, or a combination of the two. In other words, the benefits from adoption of PST include improvement in average daily gain whether or not farmers continue to sell hogs at the fixed market liveweight.

The second major mistake Meltzer makes is in applying the new estimates of the change in marginal cost to calculate changes in producers' surplus. The major mistake is to use our price and quantity changes (table 5, p. 912) in the calculations, even though these price and quantity changes are consistent only with the estimates we used for the change in marginal cost (k). In other words, Meltzer fails to make a distinction between firm- and industry-level changes. For each new value of k, there will be new changes in price and quantity. In turn, these new price and quantity changes should be used with the new value for k to estimate the new changes in producers' surplus. That is, it is incorrect to simply plug a new value for k in the formula for producers' surplus [equation (20)]

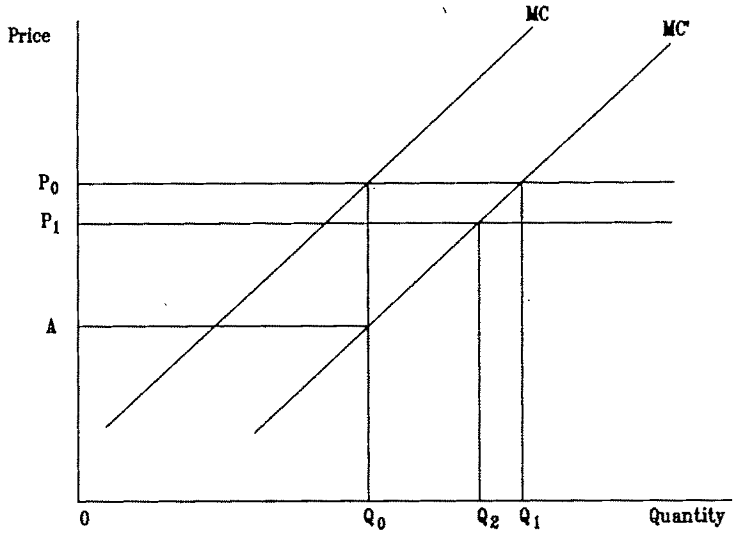


Figure 1. Impact of adoption of PST on a typical hog producer

Table 1. Expected Percentage Changes in Producer Surplus (As a Percentage of Total Value of Hog Production) from Use of PST

Increase in Feed Efficiency (%)	Variable Adoption Rate		100% Adoption Rate	
	Pessimistic	Optimistic	Pessimistic	Optimistic
Short Run	22% adoption rate			
15% (corrected Meltzer)	1.1	2.2	5.2	10.4
24% (Lemieux and Wohlgenant)	2.4	4.4	10.8	16.9
Intermediate Run	60% adoption rate			
15% (corrected Meltzer)	1.7	3.4	2.8	5.8
24% (Lemieux and Wohlgenant)	2.5	4.4	4.4	7.2

without recalculating change in price and change in quantity consistent with industry-wide adoption of PST. Because it is not mathematically possible to have negative surplus changes with the formulas we use (because they are derived assuming parallel supply and demand shifts), it should have been apparent something was wrong when a number of surplus changes turned out negative.

The correct estimates of changes in producers' surplus, which Meltzer presumably intended to calculate, are presented in table 1. We report only estimates for his "scenario 2" and for 15% improvement in feed efficiency. The values for his "scenario 1" ignore any benefits from improvement in average daily gain. Also, based on our discussion in the previous section, the estimates for 15% improvement in feed efficiency are clearly extremely pessimistic estimates of the benefits derived from daily injections of PST. Thus, we do not report the estimates for 10%. The interested reader is welcome to calculate these values using Meltzer's corresponding estimates for k in his table 1 and the appropriate formulas in Lemieux and Wohlgenant. For each value in table 1, the corresponding value for k from Meltzer's table 1 was used in our equations (17), (18), and (20). Other parameter values for the calculations are provided in table 1 of Lemieux and Wohlgenant.

The first point to be gleaned from table 1 is that all the estimates of changes in producers' surplus are positive. In the short run, values for 15% improvement in feed efficiency are roughly half those for a 24% improvement in feed efficiency. With the exception of the pessimistic consumer response case, in the intermediate run the estimates of 15% are close to the estimates for 24%. As indicated previously, there is every indication that consumers are indeed willing to pay more for the leaner pork, and processors appear to be willing to pay more for leaner hogs. Given that our estimates of the demand shifts used for the optimistic estimates are rather conservative, we would maintain that the optimistic consumer response cases contain the most likely outcomes.

Concluding Remarks

In conclusion, we believe that our estimates of the likely impact of PST on the U.S. hog industry are defensible and plausible in the context of the methodology used and assumptions about how the tech-

nology is transmitted to producers. We agree that changes in marginal costs of hog production from daily injections of PST should be treated as rough estimates of the likely impact. Indeed, that is why we chose the relatively conservative estimate of 24% improvement in feed efficiency. We disagree strongly with Meltzer's claim that the effects of PST on producers' surplus is extremely sensitive "to changes in the parameters representing the physical impact of the technology itself." This is because his conclusion is based on his erroneous calculations that "smaller estimates of (k) often result in losses in producer surplus, rather than the gains predicted by LW." We show that, when the formulas are correctly applied, the changes in producers' surplus are still positive, and that the results are considerably less sensitive than he maintains. From our viewpoint all that Meltzer has demonstrated is that you get different answers when you use different values for k—and we had to demonstrate that result for Meltzer because he misapplied our formulas.

[Received March 1991; no revision.]

References

Hayenga, Marvin, B. Buhr, K. Skold, S. Johnson, and E. Grundmeier. "Economic Repercussions of Porcine Somatotropin on the Pork Industry." Iowa State University Work. Pap., 1988.

Goodband, R., J. Nelssen, R. Hines, D. Kropf, C. Thaler, B. Schricker, and G. Fitzner. "The Effects of Porcine Somatotropin (PST) and Dietary Lysine Level on Growth Performance and Carcass Characteristics of Finishing Swine." *J. Animal Sci.* 66(1988, Supp. 1):95.

Lemieux, Catharine, and James Richardson. "Economic Impact of Porcine Somatotropin on Midwest Hog Producers." *N. Cent. J. Agr. Econ.* 11(1989):171–81.

Lemieux, Catharine, and Michael K. Wohlgenant. "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *Amer. J. Agr. Econ.* 71(1989):903–14.

Lemieux, Catharine, Michael Wohlgenant, and James Richardson. "Porcine Somatotropin (PST): What Does It Mean for Consumers, Pork Producers, Grain Farmers and Policy Makers?" Paper presented at organized symposium, AAEA annual meeting, Knoxville TN, 31 July–3 Aug. 1988.

Kauffman, R. G., E. Drachenberg, T. Hermel, D. Hull, and B. Keough. "What Is the Price Incentive for Producing Lean Hogs?" MAS 405 Senior Project, University of Wisconsin, Madison, 1988.

Meisinger, David J. "Potential Economic Impact of Carcass Modifiers." *J. Animal Sci.* 67(1989):2150–54.

Prusa, Ken, and Lauren Christian. "ISU On-Farm Test Shows PST Produces Leaner Hogs." Presentation at the Iowa Pork Congress, 21 Jan. 1991.

The EEC's Wheat Trade Policies and International Trade in Differentiated Products: Reply

Harry de Gorter and Karl D. Meilke

In a recent issue of the *Journal*, von Cramon-Taubadel (vCT) comments on our work (de Gorter and Meilke) and uses the terms "misspecification," "questionable," "incorrect conclusions," and "erroneous results." In a recent survey of the "new trade theory" and imperfect substitutes in agricultural trade, MacLaren (p. 129) concludes that our approach is "the best methodology for specifying the demand side of trade models and the relationships between imperfect substitutes in agricultural trade." However, in reference to vCT, MacLaren (p. 128) makes a qualification by stating that our approach has been used with only "some success" because of "specification errors." It is our contention that both vCT and MacLaren misinterpreted our paper. We, therefore, would like to respond to vCT and offer some observations in order to clarify any misunderstanding that may have arisen. It is important to do so because MacLaren correctly identified that traditional Armington models that analyze agricultural trade in differentiated products are inappropriate and that our approach holds much promise. Recently, Alston et al. adopt precisely our approach in reconfirming MacLaren's conclusion.

Von Cramon-Taubadel identifies three possible sources of bias in our paper: the treatment of EC's administered prices, the constant elasticity of substitution between domestic and imported wheat, and the preferences of non-EC competing exporters. We address each in turn.

First, vCT misunderstood our model and our treatment of the EC's administered price system. Our empirical model incorporated the effects of the EC price regime on food wheat consumption (both domestic and imported) only, while our theoretical model allowed for supply effects but made the simplifying assumption that threshold prices do not affect EC wheat supply. Hence, vCT's discussion of the relation of EC farm prices to administered prices is irrelevant with respect to our analysis. Our empirical results in table 2 hinge only on the assumptions that (*a*) the threshold price (adjusted for green rates and wheat quality) is a proxy for the consumption price of imported wheat, and (*b*) the reference price (adjusted for green rates) is a proxy for the consumption price of domestic wheat. If we had included the response in supply to intervention price changes, then EC exports of low quality wheat would have declined even more with a decrease in the intervention price (holding the threshold prices constant). Our major policy conclusion on the preferences of non-EC competing exporters was therefore understated. If supply is allowed to adjust to threshold price changes, then a decrease in the threshold price changes (holding the intervention price constant) has an indeterminant effect on net exports. This issue was addressed in more detail in Meilke and de Gorter.

The second possible source of bias in our model identified by vCT is that the demand parameters for EC wheat are endogenous with respect to the policy prices. This is the Lucas critique of policy analysis. We agree with Lucas, but this critique is not unique to our study; it is relevant for all studies in the economics literature that simulate alternative policy scenarios based on time-series data. One can interpret vCT's comments that gluten substitution technology and the increase in the so-called high quality 11.5% protein wheat production in the EC makes the EC wheat market a special case. Von Cramon-Taubadel himself states that gluten substitution is expensive at world market prices. It seems likely that this technology would be abandoned if the EC faced world prices, resulting in our parameters being correct.[1] The EC does not produce any high quality, 14% protein wheat that would compete directly with Canada's product. In addition, the elasticity of substitution in our AIDs model is not constant as suggested by vCT. Nevertheless, vCT states in his conclusion that our failure to incorporate the Lucas critique underestimates the effect of EC policy on trade. We therefore understate the policy implications of our simulation results.

Von Cramon-Taubadel's third and final comment is that our conclusion on the preferences of competing non-EC wheat exporters with respect to EC policy changes would hold only for those countries that export low quality wheat. This is exactly correct because our definition of a competing non-EC exporter is one that exports low quality wheat. This is because

Harry de Gorter is an assistant professor, Department of Agricultural Economics, Cornell University; Karl D. Meilke is a professor, Department of Agricultural Economics, University of Guelph.

[1] Von Cramon-Taubadel argues that the effect of gluten substitution in shifting the demand curve for imported wheat is a movement along a long-run, technology-endogenous demand curve. Perhaps it is this latter function that we estimated, and so the EC demand response to policy prices may in fact have been captured properly.

the EC is assumed to produce only low quality wheat. Hence, this entire section in vCT on the differentiation of non-EC exporters is not a comment on, but rather an elaboration, of our paper.

In conclusion, our model does not contain specification errors.

[Received December 1990; no revision.]

References

Alston, J., C. Carter, R. Green, and D. Pick. "Whither Armington Trade Models?" *Amer. J. Agr. Econ.* 72(1990):455–67.

de Gorter, H., and K. D. Meilke. "The EEC's Wheat Price Policies and International Trade in Differentiated Products." *Amer. J. Agr. Econ.* 69(1987):223–29.

Lucas, R. E., Jr. "Econometric Policy Evaluation: A Critique." *The Phillips Curve and Labor Markets*, ed. K. Brunner and A. H. Meltzer. Amsterdam: North-Holland Publishing Co., 1976.

MacLaren, D. "Implications of New Trade Theory for Modelling Imperfect Substitutes in Agricultural Trade." *Imperfect Competition and Political Economy*, ed. C. A. Carter, A. McCalla and J. Sharples. Boulder CO: Westview Press, 1990.

Meilke, K. D., and H. de Gorter. "Impacts of the EC's Common Agricultural Policy on International Prices." *J. Agr. Econ* 39(1988):217–29.

von Cramon-Taubadel, S. "The EEC's Wheat Trade Policies and International Trade in Differentiated Products: Comment." *Amer. J. Agr. Econ* 70(1988):941–43.

Books Reviewed

Allen, Kristen, ed. *Agricultural Policies in a New Decade*. Washington DC: Resources for the Future and National Planning Association, 1990, xv + 357 pp., price unknown.

The papers in this book were published "to facilitate their wide and public availability" (*iii*). Each of the separately authored chapters was part of the dialogue on issues and options pertinent to the development and passage of the 1990 farm bill, and each addresses its subject in an effective, impartial manner. The fact that the 1990 farm bill has been enacted does not detract from the value of this book, which provides the foundation needed for an understanding of the new legislation as well as insights into the evolution of U.S. food and agricultural policy.

The editor lays the foundation for current and future farm policy dialogue in the context of the past and present. While policy goals and objectives, elements of farm programs, and current concerns are succinctly reviewed, the complexity of the problem is not overlooked. The papers are organized (*a*) to review current agricultural policy, (*b*) to analyze alternative approaches to agricultural policy, (*c*) to clarify the dynamic forces that shape agricultural legislation, (*d*) to examine options for the 1990 farm bill, and (*e*) to address "forces that will affect U.S. agriculture in the coming decades" (p. 335).

Current policy is reviewed in the context of the market in which it must operate. Organizational responsibility and program structures "provide the reader with a basic understanding of the major components" (p. 27) of agricultural policy. Historical qualitative and recent quantitative approaches are used to analyze and speculate on the market setting for farm policy. Robert Thompson's description of the 1985 farm bill and his assessment of needed changes present a basis for new legislation. Alternative policies (decoupling, targeting, and supply control) are explained in a crisp, concise manner. Each paper carefully explores the domestic and international dimensions of a policy and presents its positive and negative impacts, without endorsing or condemning any particular policy alternative. Thomas Hertel's "Ten Truths About Supply Control" (p. 153), for example, compares output and acreage controls and examines domestic and foreign issues associated with supply control.

Understanding farm policy requires a knowledge of the "dynamic forces" (p. 171) that shape legislation. The papers in this book focus on current and future forces while recognizing the importance of the past. The age-old issues of stabilization and price and income protection are discussed. The current forces of change—environment, trade, and competitiveness—are treated as separate issues, but the reader is left with an awareness of their critical interface. Katherine Reichelderfer helps the reader understand "conflicting societal preferences" (p. 201), arguing in a manner that will aid resolution rather than breed antagonism. The papers on trade and competitiveness clarify the U.S. stake in international farm policy reform and evaluate "the ability of U.S. agriculture to compete" (p. 253).

John Schnittker's "Practical Options for a 1990 Farm Bill" (p. 34) is a testament to the author's understanding of the process and forces behind the farm bill and his ability to envision a reasonable compromise. Recognizing that the topics of the papers in this collection are "narrower than the wide range of factors that affect agriculture" (p. 346), the last paper focuses on a summary of emerging and future concerns. The concluding statement captures the tenor of the book and the necessary character of good farm policy: "Responsiveness may therefore be its most important goal in the new decade" (p. 346).

From an econometric standpoint, this is not a strong collection; but, because it provides powerful insight into U.S. food and agricultural policy, it is recommended reading. The authors have crystallized a vast array of complex information into an easily understood analysis of domestic and international issues, forces, and alternative policies. Moreover, because the papers are edited to read like textbook chapters, this book could be used in total or in part as assigned reading for an introductory policy course.

Allan E. Lines
Ohio State University

Garst, Rachel, and Tom Barry. *Feeding the Crisis: U.S. Food Aid and Farm Policy in Central America*. Lincoln: University of Nebraska Press, xii plus 275 pp., $12.95.

Garst and Barry state they wrote this book to offer a much-needed perspective about the U.S. role in food distribution and production in Central America. They examine critically the objectives and consequences of U.S. food aid and agricultural policy in Costa Rica, El Salvador, Guatemala, and Honduras during the 1980s. They conclude that food aid and associated farm programs are feeding crises. While food aid is commonly regarded as the most beneficial and positive aspect of U.S. involvement in Central America, they argue that food aid and the associated farm programs are part of the problem rather than part of a solution.

Chapter 1, "The Food Rushes In," introduces the food aid program in terms of the economic, political, and humanitarian objectives. U.S. food aid legislation, Public Law 480, was passed by Congress in 1954. The legislation and other documents define several often conflicting objectives: develop and expand export markets for U.S. agricultural commodities, com-

bat hunger and malnutrition, provide humanitarian relief to victims of disasters, encourage economic development in developing countries, and promote the foreign policy of the United States. The conflicts among the objectives and the different institutions who implement the food aid program (State Department, U.S. Treasury, Agency for International Development, U.S. Department of Agriculture, Department of Transportation, Office of Management and Budget, Central Intelligence Agency, Peace Corps, and White House) plus the United Nations and recipient country institutions indicate how difficult a simple food assistance program has become.

The large increases in food aid and the manner in which it functions are discussed in chapter 2, "Food as Money." Food aid flows to the countries as Title I government-to-government concessionary sales frequently in local currency and Title II donations for humanitarian causes. During the 1980s, Title I increased from less than $5 million to over $100 million and Title II donations from $10 million to about $25 million.

The link between food aid and food security is examined in chapter 3, "Food Aid vs. Food Security," and chapter 4, "Food Aid's Reform Diet." Here the authors argue that food aid encourages import dependency and that more is imported than would occur on a commercial basis because of the concessionary terms. In addition, food aid creates strong disincentive effects for local production leading to a stagnation of domestic food production. Food aid also leads to a change in consumption habits as consumers shift from locally produced foods, such as corn and beans, to imported products, such as wheat. The authors argue that food aid is being used to push the governments of these countries to restructure the economy toward privatization, comparative advantage, and the free market, and that such reforms will harm small farmers.

Chapter 5, "Food for People," discusses the donated food aid programs and the appropriateness of this food aid as a solution to the problem of hunger and nutrition. This includes supplementary feeding programs, food-for-work programs, and emergency relief programs. The many problems of these programs are identified, particularly the institutional ones, because of the large number of nongovernment organizations, international agencies, and local institutions who participate in the programs. Chapter 6, "Food for Development," continues the discussion of the food-for-work program, which links food aid with social and infrastructure development projects. In spite of the problems of food-for-work programs identified by the authors, they surprisingly conclude that the program is appealing as a development resource and tool for change.

"Food for War," chapter 7, examines the military and political uses of food aid. They point out the irony of a program known as Food for Peace that is frequently used to achieve military objectives in pacification programs and war-related projects.

Interested readers will find the book offers a very helpful summary and critique of the food aid assistance program to these Central American countries. The book should be of value to food aid policy makers, administrators, and students who want a current summary of the problems of food aid in developing countries.

While the book is quite critical of the food aid program, the critique advances nothing new about the problems of food aid that have not been examined in the literature several times in the past thirty-five years. The authors offer several recommendations on how the food aid program could be improved. A good many of their recommendations have been tried and failed in one country or another, and other recommendations—such as increased supervision of food aid—are too general and/or too costly for implementation. The most surprising part of the entire book is the concluding chapter in which the authors, after more than 180 pages of criticism of the food assistance program, recommend that the program be continued instead of terminated. This recommendation is not consistent with the title of the book nor the arguments of the previous chapters. A logical conclusion of the evidence presented from this book is that food aid programs should be terminated.

Donald W. Larson
Ohio State University

Hayami, Yujiro, Ma. Agnes R. Quisumbing, and Lourdes S. Adriano. *Toward an Alternative Land Reform Paradigm: A Philippine Perspective.* Manila: Ateneo de Manila University Press, 1990, 209 pp., price unknown.

"The purpose of this book is to search for an optimal land reform design. 'Optimal' here means feasible yet effective in reducing rural poverty and inequality by considering the existing political market conditions" (p. 4). The book represents a continuation of work reported in a monograph which was reviewed by Thiesenhusen for the *AJAE*. Much of what was said in the earlier review remains applicable for this new publication.

There are seven chapters. The first on equity and efficiency will be of most interest to the general development economist. Here the authors present three basic considerations for successful land reform—rules must be simple, transparent, and uniformly applied; and discretionary government involvement in implementation minimized. With these considerations, they suggest four core components for a new program design—a ceiling on aggregate land owned, a progressive land tax, deregulation of land tenure contracts, and progressive rent on public land lease.

A model of the political market for land reform is also sketched in chapter 1, and the plan of the study is presented as follows: "chapter 2 identifies the unique characteristics of the Philippine agrarian structure in terms of its history and in relation to its international experience. Chapter 3 reviews past land reform pro-

grams in the Philippines and their accomplishments with reference to the political market model. Chapters 4–6 report on the results of our field studies: chapter 4, the distortive effects of past and present land reform programs on the rice sector in which reform efforts have traditionally been concentrated; chapter 5, the economic and social conditions surrounding the cultivation of traditional cash crops (sugar and coconut), with special focus on possible scale economies in production and processing; and chapter 6, the conditions of modern agribusiness plantations in Mindanao, which grow bananas and pineapple for export, to determine if their production organizations may be changed into contract farming without decreasing productivity, and the extent of public land use in hills and mountains in such frontier areas to solve landlessness. Chapter 7 summarizes our findings from the Philippine case study and presents a perspective on land reform in the Third World" (p. 18). Pages 168–209 are made up of appendices giving excerpts from the Philippines' land reform legislation and a presidential decree, endnotes, a glossary, references, and an index.

The reader has no good economic basis for assessing whether the proposed land reform paradigm is feasible or would increase efficiency. There was no apparent attempt to measure the cost of implementation and the potential benefits in terms of the number of people served and the extent of their benefits. The fieldwork was based "on informal discussions with tenants, landlords, plantation managers and laborers, agribusiness executives, local officials and politicians" (p. 18), and provided very little information for quantitative estimation. This reviewer was not able to judge the feasibility and efficiency of the paradigm from a political perspective.

New evidence to support the argument that there are few economies of scale in the Philippine agriculture was based largely on yields by farm size and was inadequate to be convincing.

Crops important to the Philippines are nearly all heavily traded in international markets. However, in the presentation of results the authors did not consider possible effects of their paradigm in world markets. Graduated land taxes and lease charges and any increased cost of coordinating production from small farmers would likely lower comparative advantage and, over time, encourage flight of capital to competing areas.

The work expresses a sense of both land and agricultural fundamentalism. This comes through in the authors' return to the concept of the agricultural ladder, which is becoming increasingly obsolete because of population pressures. Also, with the exception of the following sentence, the authors treated the agricultural sector as being closed: "Since it is unrealistic and undesirable to absorb the increasing rural population entirely in agriculture, policies to encourage the creation of nonagricultural employment opportunities must also be implemented" (p. 127). An admissible hypothesis is that it is cheaper per worker to create employment outside of the agricultural sector, and policy makers need hard evicence on such matters.[1] Also, the authors did not give sufficient recognition of the importance of the strength of the off-farm sectors to the success of the land-reform programs in Japan, Taiwan, and South Korea.

Our profession is richer because of this effort, and persons with an interest in land reform and economic development will want to read it.

Max R. Langham
University of Florida

Reference

Thiesenhusen, William. Book review of Hayami, Quisumbing, and Adriano, *In Search of Land Reform Design for the Philippines*. *Amer. J. Agr. Econ.* 70(1988)755–56.

Jacobson, Robert E., and Con O'Leary. *Dairy Co-op Issues in Ireland*. Center for Cooperative Studies, University College, Cork, Ireland, 1990. 144 pp., price unknown.

This is an interesting monograph about cooperative principles and a study of how well they are being practiced by dairy cooperatives in Ireland. The content has implications for U.S. cooperatives.

Using commonly adopted cooperative criteria established by the International Cooperative Alliance (ICA), the authors surveyed fifteen Irish dairy cooperatives, including the "big six." Irish dairy cooperatives were found to deviate from allocating traditional net earnings to members, but, instead, keep earnings as unallocated reserves. Another characteristic of many Irish dairy cooperatives is that nearly one-fourth of the milk suppliers are not members of the co-ops, and nearly one-half of the members are inactive as patrons. As a consequence, they have no strong cooperative loyalty.

A major (stated) reason for converting into a Public Limited Company (PLC) was to gain additional capital. It would be interesting to have information on how successful these cooperatives were compared to other cooperatives in gaining capital. Apparently, when a profit opportunity was presented to milk suppliers, they did respond by acquiring shares in the PLC, but management believed they would not provide capital to the cooperative as it was currently structured.

What have been the consequences? Three of the largest five have created a PLC for investors, but there is no basis for members who were not PLC holders

[1] If one had divided the 14.66 million hectares of alienable and disposable lands equally among the rural population of the Philippines in 1987, there would have been 0.428 hectare per rural inhabitant, or, assuming a family of 6, 2.57 hectares per family. At current World Bank population projections and assuming the rural-to-urban migration rate remains the same, this latter figure will be 2.05 hectares in the year 2000. At best, land reform is only a very partial solution to the Philippines' rural poverty problem.

to have a market for their cooperative shares. This benefits investors and members who are investors but not all cooperatives members. It also benefits management because most chief executives and key management have preferential rights to purchase PLC shares. As the authors suggest, there were other ways to accomplish the infusion of capital into the cooperative.

The development in the Irish cooperative dairy industry can be summarized as "cooperation gone wrong." It illustrates (*a*) the failure to adhere to the principle of returns allocated to patrons; (*b*) the failure of cooperatives to devise systems that allow members' interest to reflect current values; (*c*) failure to devise systems of management compensation that adequately reward performance; (*d*) failure of boards of directors to adequately exercise control of management (and to constrain their greed); (*e*) failure to purge inactive members, so they would not have a vote on matters that no longer concerned them; (*f*) failure to recognize that public infusions of capital via subsidies and (EEC) grants into the dairy industry might not continue; and (*g*) failure to recognize that expansion and investments based on subsidies instead of market signals is like building on shifting sand.

Why did the Irish dairy cooperatives retreat so far from traditional cooperative principles? While the authors do not make this charge, it seems reasonable to fault the Irish Cooperative Organization Society (ICOS), the national cooperative organization that gives leadership to cooperative development, operations, and organization, including the active seeking of European Community subsidies. When centralized oversight such as ICOS was to provide fails, firms seek their own self interests.

Every person interested in cooperatives should find chapter 8 required reading. They would find these warning signals: (*a*) Every cooperative that converted to PLC had ignored several cooperative principles. The cooperatives' voting shares were not limited to active members. The inactive members had a vote, but no need for the cooperative and no way to recover their limited share capital. Since the organizations did not operate as cooperatives, there was no reason to develop any cooperative loyalty. (*b*) They had not permitted shares to reflect current values nor to devise a system for share transfers.

A number of U.S. cooperatives will need to give attention to several of these concerns also.

Leon Garoyan
Center for Cooperatives
University of California, Davis

Neher, Philip A. *Natural Resource Economics: Conservation and Exploitation*. Cambridge and New York: Cambridge Univesity Press, 1990, ix + 360pp., $62.50, $24.95 paper.

This is a presentation of theory and mathematical tools that are useful in the analysis of renewable, nonrenewable, and environmental natural resources. Its approach is primarily control theory, but this is made unusually acessible to the reader through well-motivated, intuitively appealing approaches. The book reviews intermediate production and cost theory and applies it primarily to fisheries and mining as examples of renewable and nonrenewable resource systems. There are brief treatments of forestry, aquifers, and environmental issues.

The author asserts that parts of the book can be used at all levels, but, in my experience, it would be accessible only to advanced undergraduate majors and graduate students. While the author is good at motivating and explicating models and math (including a slight attempt to present basic calculus), the book is unremittingly mathematical, and the student will be kept busy enough following the theory and math, let alone trying to learn differential calculus. Users must be facile with differential calculus.

The book has four parts. The first consists of excellent treatments of "static" analyses of fisheries, forests, and the mine. The author, in fact, goes considerably beyond the usual static presentation through the use of two-period models that allow future conditions to be taken into acount. There is, for example, an excellent demonstration that optimal fish stocks can be either greater than or less than the stocks generating maximum sustainable yield, a result usually obtainable from only dynamic programming or control theory treatments.

Part II provides basic tools on which the rest of the book rests: an intuitive introduction to the efficiency conditions resulting from control theory for resource firms (chapter 5), a formal but fairly clear introduction to control theory (chapter 9), reviews of production and cost theory, and firms' supply and demand functions. The key development of the book occurs in chapter 5, where the author presents the "static" analysis of a producing firm (trucking services) and that for an asset or portfolio management firm (one that buys and leases trucks to trucking firms), then merging the two models into one of a firm performing both functions. From this merged model, the three key optimality conditions are derived: the "maximum principle" to determine the optimal use rate of the variable input, the "portfolio balance" condition that determines the optimum level of the stock input, and the "dynamic constraint" that determines changes in the stock input from natural growth (if any) and the pattern of use. The correspondence of the model and those conditions with the tasks of a resource firm are clear. The motivation, unfortunately, is substantially marred by failure in the trucking example to differentiate between flows of trucking services and stocks of trucks. The use of the "primal" model for the firm (using the production function) and the "dual" (using the cost function) in a somewhat nonstandard form without introduction will be bothersome to students.

The remainder of the book, parts III and IV, apply the three basic optimality conditions to further analysis of fisheries and mines. Environmental issues are

treated only lightly. Control theory as developed in chapter 9 is really little used, with the exception of the use of the transversality conditions in analyzing use paths of exhaustibles over finite time horizons. The use of taxation in various forms to substitute for scarcity values in open access systems is reviewed.

Each chapter ends with exercises, and the last chapter presents specific mathematical examples of the mining problem. The index is too brief to be of much use and, like earlier parts, suffers from some typographical errors (transversability instead of transversality).

Overall, the author brings a unity to the treatment of natural resources that is unique. The three optimality conditions prove their relevance time after time. One learns very useful tools from the book, but the unremitting mathematical treatment will not suit all needs.

Chuck Howe
University of Colorado

Pearce, David, Edward Barbier, and Anil Markandya. *Sustainable Development: Economics and Environment in the Third World.* Aldershot, England: Edward Elgar, 1990, xi + 217 pp., price unknown.

Environmental problems in developing countries arouse widespread concern. Tropical deforestation affects the climate and threatens numerous plant and animal species with extinction. Soil erosion impinges on food production and water resource development. Air pollution in the major cities of Africa, Asia, and Latin America strains human endurance.

To date, few economists have addressed the developing world's environmental crisis. Among those who have are David Pearce, Edward Barbier, and Anil Markandya of the London Environmental Economics Centre, which is a joint initiative of University College London and the International Institute for Environment and Development. Their work is summarized in this brief volume.

The book begins with an examination of the concept of sustainability. Accepting that it should be a primary guideline for economic policy making, the authors contend in the first chapter that "constancy of the natural capital stock" is "the key necessary condition" for sustainable development. The focus of discussion narrows considerably in the second chapter, in which the position is taken that using positive discount rates to evaluate resource management projects is consistent with sustainable economic development. Theoretical as well as empirical arguments are advanced. The third chapter, which is the shortest in the book, contains some general thoughts on evaluating the environmental impacts of proposed projects.

After having presented overarching concepts, the authors turn to six case studies. The causes and consequences of watershed degradation in Java and deforestation on Indonesia's Outer Islands are described. Soil erosion, loss of natural vegetation, and related forms of land degradation in Botswana, Nepal, and Sudan are examined. Finally, deforestation in the Amazon Basin is discussed.

Aside from containing accounts of some interesting research, *Sustainable Development* provides guidance for policy making. Clarification of the idea of sustainability is particularly welcome. The rationale for discounting is also laid out very well. In addition, policies that stimulate waste and mismanagement of natural resources are a major focus of the case studies.

Sustainable Development also has considerable value as a teaching tool. Because environmental economics is rarely practiced outside of affluent nations, virtually all textbooks on the subject focus on resource management trade offs arising in a modern, industrialized society. While many environmental issues facing, say, Mexico City or Kenya closely resemble the issues with which Milan and Iowa must deal, many others (e.g., linkages between renewable resource depletion and widespread poverty) do not. This book specifically addresses poor countries' environmental problems.

Individuals wishing to use *Sustainable Development,* either as a guide for policy making or as a textbook, should be aware of its limitations. There are typographical errors (e.g., in the third mathematical appendix of the second chapter) that will cause people without a strong background in economics to be confused. In addition, the book's coverage of issues is far from comprehensive. Urban pollution, for example, is not addressed and, other than the chapter on deforestation in the Amazon Basin, the case studies are drawn exclusively from Africa and Asia.

On a more substantive level, this reviewer has two concerns. First, the authors' position that policy makers should maintain a constant stock of natural capital (i.e., that the "true" economic value of environmental wealth should not be allowed to decline over time) can be challenged. For example, it is entirely possible for a country to enhance its present and future welfare by "mining" exhaustible or even renewable resources and investing the proceeds in human capital and other nonenvironmental wealth.

Second, neither in the first three chapters' discussion of general concepts nor in the six case studies are contingent valuation, hedonic pricing, and related techniques for estimating nonmarket environmental values presented or demonstrated. This is ironic in light of the stress placed on taking those values into account when making public policy.

Individuals using *Sustainable Development,* either to inform policy making or in the classroom, should not find it difficult to overcome these shortcomings. Complementary readings can be used to present alternative economic perspectives on sustainability as well as nonmarket evaluation techniques. This reviewer is enthusiastic about using the book as a "core reference" because it provides a highly readable overview of the economic issues raised by poor countries' environmental problems.

Douglas Southgate
Ohio State University

Pollack, Norman. *The Humane Economy: Populism, Capitalism, and Democracy*. New Brunswick NJ: Rutgers University Press, 1990, xiv + 214 pp., $40.00.

The Humane Economy is the second of two studies by the author on Populist thought in America. *The Just Polity* "presented the constitutional, legal, and moral features of the Populist thought" (p. x). *The Humane Economy* studies the economic frame of reference for the Populists' construction of democratic capitalism: "I present a succinct account of the Populist synthesis of economics and ethics to form a democratic polity that was outside the mainstream of the American historical experience" (p. xiv).

This book summarizes one set of human aspirations behind a recommended system of political economy. Pollack assembles representative writings of Populists to provide the participants' account of Populist philosophical development and activism urging a midcourse restructuring of democratic capitalism in the America experiencing rapid expansion and industrialization in the late nineteenth century. The book provides an interesting example of the philosophical, political, historical, and ethical underpinnings of an economic system.

Populists held a primary objective of enhancing the welfare of the masses. The construction of an economic system was merely a means to achieve that objective. So, many apparent contradictions appear in their proposals for adjusting the economic system. Populists were "citizen democrats who sought rectification of overall conditions and a more humane political and social order" (pp. 10–11). The fundamental purpose of the Populist movement was "to provide an alternative mode of human freedom in refutation of the economic, political, and cultural dominance of the expanding corporate system" in modern America (p. 51).

Tactically, Populists fought together along one central theme: antimonopolism. Industrialization and modernity led to the concentration of wealth and power. Concentration of wealth resulted in frivolous expenditure and reduced opportunity for the masses. Concentration of power led to corporate sovereignty rivaling that of government. Concentration of wealth and power thereby resulted in restrictions on economic security and personal independence, a degraded state of human welfare.

Populists were neither socialistic, equalitarian, nor collectivist. They emphasized personal ownership of property, income differentials for performance, a capitalist economy, and promotion of the individual's worth. But they recommended government regulation (and sometimes ownership) of industry and decentralization of wealth as prerequisites for a just society, with the benefits of modern industrialism accruing to the masses. The "Populist interpretation of capitalism included faith in constitutionalism and the democratic state as prerequisites of a morally satisfying, and economically and politically just, capitalistic system" (pp. 14–15).

The populists supported capitalism when it served their central purpose of enhancing human welfare, but they did not support complete laissez-faire when it led to concentration of wealth and power. Populists had three causes: governmental ownership of railroads, regulation of banks, and broader land ownership. Property was perceived as a means of livelihood rather than a means for domination. Credit and transportation were lifelines to capital and markets which made livelihood possible, and they were controlled by corporations.

Pollack also reveals how philosophical positions are constrained by existing realities. Populists might have considered governmental ownership of land with democratic distribution of its use. But land ownership was a major objective of farmer Populists in an era of foreclosures by banks and railroads. Similarly, in the South, enhancement of liberty and land ownership was secondary to preservation of racial class distinction. Liberty for all had its limitations.

The Populists envisioned an ideal constitutional society open to all, with a New England townhall democracy, a broad distribution of wealth and opportunity, and a government interested in protecting life, liberty, and the pursuit of happiness for the masses. But the Populists lost. Their attempt to restructure American capitalism failed to gain enough support for adoption. "One is forced always to treat Populism in the conditional senses, as an actuality that United States historical development reduced to a hypothetical construct because it was never permitted a proper test" (p. 158).

Marc A. Johnson
Kansas State University

Prosterman, Roy L., Mary N. Temple, and Timothy M. Hanstad, eds. *Agrarian Reform and Grassroots Development: Ten Case Studies*. Boulder CO: Lynne Rienner Publishers, 1990, x + 339 pp., price unknown.

This is an interesting collection of agrarian reform experiences in a variety of regions and covering a very broad spectrum of cultural and land tenure institutions. In addition to introduction and conclusion sections by the editors, the book contains ten chapters devoted to case studies. Agrarian reform programs are covered for the Philippines, the state of Kerala in the south of India, Bangladesh, China, the countries of Central America, Mexico, Brazil, the Soviet Union, Poland, Hungary, and Zimbabwe. A chapter on the land question in South Africa is also included. The authors are from a number of U.S., and one British, universities in the fields of economics, political science, law, and geography. One author is with an East Coast consulting firm, and one of the editors is the executive director of the Curry Foundation, which sponsored and supported this project. The chairman of the Curry Foundation's board of trustees wrote the foreword to this volume.

Given the great diversity among the regions and the countries covered, and adding to this the always

very unique features of agrarian reforms in different institutional settings, it is difficult to present generalizations which characterize this book. From past experience and recent work on these issues, I judge the case studies to be extremely well done. The authors are for the most part objective in their treatment and analysis of the specific agrarian reforms. Indeed, this book should be very useful as supplementary reading for undergraduate and graduate social science courses in area and development studies.

I do have some differences with the editors who wrote the introductory and concluding sections, however. It would have been helpful to the reader if the editors had attempted to draw from the case studies a classification system as to the several routes by which these reforms were brought about (for example, outside force, revolution from below, military coup and/or revolution from above, new postcolonization government, legislation in a democratic setting, and so on). This exercise would surely have made them less likely to ignore the very significant political obstacles to reform which are frequently noted by the case study authors.

It seems to this reviewer that an unstated assumption of the editors is that governments can actually be induced to carry out an agrarian reform through education, persuasion, and financial assistance. "Support and encouragement from outside played an important role in the South Vietnamese and Salvadoran land reforms, as it did in the postwar reforms in Japan, Taiwan, and South Korea. . . . [O]fficial foreign aid can have a vital role with respect to landowner compensation" (p. 315). I do not believe that the South Vietnamese and Salvadoran reforms fall within the same class as those in Japan, Taiwan, and South Korea. And I do not believe that official foreign aid had a key role in landowner compensation in these or other reforms.

Galbraith's admonition of forty years ago must be recalled: "If the government of a country is dominated or strongly influenced by the landholding groups—the one that is losing its prerogatives—no one should expect effective land legislation as an act of grace. . . . The world is composed of many different kinds of people, but those who own land are not so different—whether they live in China, Persia, Mississippi, or Quebec—that they will meet and happily vote themselves out of its possession." Or, as stated by the authors of chapter 3 on Bangladesh: "Agrarian reforms do not occur simply because they are enacted into law. Agrarian reforms do not happen because they appear to be justified as a rational means of providing the basis for broader participation in agricultural innovation, increases in agricultural productivity, improved distribution of income, social justice, or long-run political stability. Agrarian reforms do not happen in any country because they appear to outsiders to be necessary. . . . Such reforms occur when those who govern also have the capacity to employ, when necessary, coercive means to neutralize the inevitable opposition of traditional landowners to reform measures of any kind" (p. 98).

I believe at least part of the problem rests with a misinterpretation of the land reform experiences in Japan, Taiwan, and South Korea, and a consequent unreasonable and overoptimistic expectation of using these experiences as a model for other reforms. At this point the premise stated in the foreword comes to be important: "We expect this book—the first of its kind—to stimulate policymakers to look again at the successes of our development aid programs after World War II, when land reform was enacted with U.S. support in Japan, Taiwan, and South Korea, establishing their system of owner-operated agriculture and laying much of the foundation for the economic progress they have achieved" (pp. ix–x). But these cases represent more than "support and encouragement from outside" (p. 315) or of a "political will in a strong central authority, such as MacArthur in Japan or Chiang Kai-shek in Taiwan" (p. 315). These central authorities respresented, as noted by the author of the chapter on South India, "the U.S. occupation of postwar Japan [and] the conquest of Taiwan by nationalist forces who had just lost a peasant war on the issue of agrarian reform on the mainland" (p. 51). Among a number of circumstances uniquely favorable to carrying out a land reform in these countries and which cannot readily be duplicated, the most important was the fact that the sovereign power rested with outside forces who dictated the reforms' design and implementation.

There are, of course, lessons which can be learned from the successful East Asian experiences with land reform. But one must exercise constant vigilance and caution and be forever conscious of the uniqueness of conditions lest recommendations based on unwarranted analogies be substituted for an in-depth understanding of the case in question. If some of these unstated—and uncalled for—assumptions can be ignored, this book can be a very good source of readings on a wide range of land reforms under a broad spectrum of physical, social, cultural, institutional, political, and economic settings.

Peter Dorner
University of Wisconsin

Reference

Galbraith, J. K. "Conditions for Economic Change in Underdeveloped Countries." *J. Farm Econ.* 33 (1951):695–96.

Raeburn, J. R., and J. O. Jones. *The History of the International Association of Agricultural Economics: Towards Rural Welfare World-wide.* Aldershot, England: Dartmouth, 1990, x + 187 pp., price unknown.

One advantage of living a long time (I spent part of my 68th birthday writing this review!) is to increase the probability that you will cross paths with other patriarchs, some of whom may be "famous" or who

might have performed in such a manner as to merit their names and deeds being recorded by historians. Put in another way, each of us immortalize ourselves in our own fashion. The names of many agricultural economists of such fame—and their deeds in this international society—comprise the principal message of this volume, *The History of the International Association of Agricultural Economists* (IAAE). The book chronicles for posterity and for the profession those activities of the IAAE over the past seventy-five years which need to be remembered: events, achievements, and personalities.

Indeed, if the IAAE has a place in history, it is principally because of the personalities, epitomized by IAAE founder Leonard Elmhirst, who, through the years, have struggled to find a forum in which agricultural economists from all over the world might visit, speak, and exchange professional discoveries. That history is developed in adequate fashion here; but if one desires more detail, it can be obtained at IAAE archives at Oxford University.

When I first opened this book I was struck by the picture, "At The First Conference" (1929). My reaction was: I knew and visited with many of these stalwarts; and I and my generation are the last to bridge to these founding fathers. Moreover, we have the mission to carry on their vision of IAAE "a stimulus to science and to friendship" (G. F. Warren). This volume is not large for a history. Preface and acknowledgement are followed by five parts: Introduction; "The Foundation 1928–1934"; "The Conference"; "Organization, Finance and Management"; and "Epilogue," which parts are, in turn, divided into eleven chapters. A "Sources and Notes" section is helpful for detailed references.

It has been my good fortune to attend most of the Post-World War II conferences and to have exchanged views and pleasantries with many of the earlier, history-making pioneers. The book outlines in excellent manner the foresight and contribution of early organizers of IAAE conferences.

It was no easy task for them; and support through the years has been increasingly difficult to come by. But for the support of Oxford University; the Farm Foundation; the Ford, Kellogg, and Rockefeller Foundations; and other such institutions, the conference would have had difficulty in surviving. In addition, the personal devotion of individuals like Elmhirst and a host of successive colleagues and the financial underwriting of their universities and other employers, national and international, have assured continuity of purpose.

The principal theme of the book is the happenings at the IAAE meetings, beginning with that first one in 1928. Problems of program design and development, relations with host countries, and the politics of leadership are appropriately discussed.

Above all, this book—though a bit fragmented—is imbued with sentiment, and rightly so for such a work. But where does IAAE go from here? Unfortunately the authors do not cover the XX Conference (Argentina 1998), which in many ways characterizes what I believe to be the dilemma of the IAAE. Summarizing the thread of that dilemma in my own words, I ask the authors' and readers' indulgence to present several questions:

(*a*) What is the continuing purpose of the IAAE conference? If it is structured principally around another professional paper-presenting meeting, there is danger that a main purpose of this historic conference—a triennial meeting of professional friends to discuss, in relaxed fashion, their scientific ideas—will have been lost. To have most of these on the program dashing in, giving their "truth," then dashing on to their next forum negates the historical spirit of the conference. How do we assure against the narrowing of the forum?

(*b*) How do we protect the conference from being dominated by the big entities; namely national and international organizations? A subquestion of this: how does IAAE evoke continued presence from the developing world and finance from governments for constituent scientists?

(*c*) Where do new leaders come from? How do we induce a new crop of leaders to step into the shoes of many of the selfless leaders of the past to assure a restructured, dynamic, but historic tradition? Where are the new Johnsons, Dams, Petits, Brittons, and the Hildreths, and so on?

(*d*) Finally, how shall we organize and finance for the future? I had the pleasure of recently meeting with IAAE President John Longworth and President-elect Csaba Cśaki (Brisbane, Australia, February 1991). It was comforting to be apprised of the fact that they are giving major attention to, and are devoting much effort to, the above issues.

When a new chapter of this history is written in years ahead it will no doubt demonstrates the IAAE still holds a strong place in the pantheon of values among agricultural economists around the world.

Jimmye S. Hillman
University of Arizona

Reference

G. F. Warren. *Final Statement, Proceedings, 1934 Conference of IAAE.*

Riad El-Ghonemy, M. *The Political Economy of Rural Poverty: The Case for Land Reform.* London: Routledge, 1990, 337 pp., $52.50.

Land reform is a powerful slogan but a tricky analytical concept. This truism reappears throughout Riad El-Ghonemy's valiant attempt to focus data from a variety of countries on land reform efforts since World War II. He brings to the task some forty years of professional experience and often personal contact with land reform programs, primarily through his work with the Food and Agricultural Organization of the U.N. His focusing device is to concentrate on the extent to which land reforms have reduced rural poverty.

Each country's land reform is different, reflecting historical antecedents, implementing capabilities and goals. The common elements of those he classifies as complete land reforms have included the provision of direct access to individual or collective land ownership for at least two-thirds of agricultural households, involving over half the cultivable land, the absorption of at least two-thirds of landless peasants, and rising per capita food production (p. 186). China and South Korea meet this test, as did Cuba and Iraq in their initial land reform efforts, but with disappointing subsequent results in per capita food output.

Under the category of partial land reforms he includes Mexico, Bolivia, Peru, Iran, Sri Lanka, Algeria, Syria, Egypt, India, and Pakistan, in descending order of direct beneficiaries as a percentage of total agricultural households (pp. 254–55).

The record with respect to reduction in rural poverty is spotty. Where population growth rates have been high, they have overpowered initial beneficial effects of land reform. Still, the author finds persuasive evidence of the benefits of land reform in raising the social status of rural people. In his view, land reform is the rural expression of anti-monopoly policy, and "is basically a social and political issue" (p. 282).

With emphasis on justice and equity in wealth distribution, Riad El-Ghonemy uses both case studies and aggregative data to challenge assumptions that have retarded land reforms, including (pp. 282–84):

That "land reform has no place where there appears to be a shortage of land to redistribute."

That "there is a high extent of accessibility to land ownership through transactions in the land market."

That "high rate of agricultural growth and adoption of new technology are conditioned upon the dominance of large firms."

His data lead him to conclude that all of these assumptions are false.

In his view, land reform is an ongoing process, not a once-and-for-all redistribution, and it has typically been attempted in settings in which governments and their technocrats are not neutral referees but are major owners or controllers of land (p. 284).

This accounts for much national and local opposition, but what accounts for the decline in worldwide interest in land reform that he detects since about 1980? After a series of conferences, and national and international commitments to land reform in the 1970s, international agencies turned to other things in the 1980s, supported by national governments hostile to land reform in at least the United States, the United Kingdom, and West Germany. Under Reagan in the United States, "land reform as a policy issue in American foreign policy is dead . . ." (p. 59).

Why this negative view of land reform in the face of supportive evidence as mobilized by Riad El-Ghonemy? He attributes the turn-away to growing concern about "mounting problems of debt, inflation, trade and balance of payment deficits facing many LDC's" (p. 295). He could have continued by including most of the developed countries in his list.

Perhaps a more telling answer would be to reflect on the degree to which developed countries in recent years have been preoccupied with macroeconomic variables, to the near exclusion of interest in policies at the micro or firm level. The computer age demands aggregate data, and these are reflected in the nature of problem perception and resulting policy prescriptions.

Against this background, the effort in this book to redress the balance by a combination of case studies, cross-sectional, and time-series data is a welcome attempt to see a large problem area whole. It is a deeply felt distillation of a lifetime of experience by a highly qualified observer. He has enriched the literature.

Philip M. Raup
University of Minnesota

Sanderson, Fred, II, ed. *Agricultural Protectionism in the Industrialized World.* Washington DC: Resources for the Future, 1990, 488 pp., price unknown.

The book contains papers that resulted from a cooperative effort by an international group of scholars who participated in workshops held in 1986 and 1987 and at a conference in 1989. The project was undertaken by the National Center for Food and Agricultural Policy at Resources for the Futures and was designed to "assess national agricultural policies and their implications for trade and to distill lessons and conclusions that may be useful to policymakers" (p. xix). This book is composed of two parts. The first part (chapters 1 through 6) presents "careful expositions of the domestic policies of the six major industrialized nations that are the most important traders of agricultural products" (p. xvii); in the second part (chapters 7 through 10), a global view of agricultural protection is presented. This book should serve as an excellent reference for applied courses dealing with international agricultural policy. The chapters on individual countries provide background material on the national and international policies of the six developed market economies for scholars conducting research in those areas.

The core of this book reveals the costs for their trading partners of protectionism by the industrialized world as well as the costs to the countries which impose that protectionism. The historical evolution of farm programs, their objectives, the political influence of farm groups, and the range of policy instruments that are used to achieve the farm program objectives are discussed regarding each of the six market economies. Characteristics of the commodity support programs, import restrictions, export expansion policies, and attempts by national governments to reduce subsidies and to liberalize trade are examined.

Whether farm price support programs have achieved their objectives is challenged throughout the book. In chapter 1, Gardner critically analyzes U.S. policies: "The evident lack of connection between the 'farm crisis' of the 1980s and the distribution of payments has renewed questioning of the purposes of U.S. farm

programs" (p. 29). It is recommended that a more efficient alternative of assisting farmers "would be a system of direct payments not tied to production . . ." (p. 58).

In chapter 2, Koester and Tangermann present an anatomy of the complicated European Community (EC) farm policies (CAP) and the decision-making process within CAP. Farm policies in the EC are criticized in the sense that CAP has "failed in its basic purpose of *securing adequate farm incomes*" (p. 96). If CAP continues as it has in the past "the community would continue to register significant welfare losses, both domestically . . ., and internationally in the sense of a self-imposed deterioration in the terms of trade, resulting from the price-depressing effects of export subsidies" (p. 103).

In chapter 3, Meilke and Warley give distinct features of Canadian agriculture, including the low border protection for most farm commodities, the nature of the marketing boards, transportation subsidies, and the distinction between the federal and provisional government domain. It is stated that the "exposure to world market conditions provides the stated justification for many of Canada's agricultural commodity programs, which are designed to provide producers with some protection from cyclical and sporadic market instabilities and from the policy-induced distortions transferred from world markets" (p. 120).

Hayami discusses Japan's agricultural policies in chapter 4. He provides a well-written theoretical background for protectionism: "The industrial growth rate tends to be higher in countries that are late to borrow technology . . ." (p. 190). "The sharp decline in agriculture's comparative advantage in Japan underlies the increase in agricultural protection and the decrease in food self-sufficiency" (p. 188). This chapter sheds light on why agricultural protectionism has been tolerated in Japan, given the impact it has had on consumer prices.

Australian policy instruments and institutional changes governing rules of trade are examined by Edwards in chapter 5. Considering that agricultural protection is relatively low in Australia compared to other countries, "Australia can claim that its policies for agriculture are consistent with using resources where their economic productivity is highest with trading according to comparative advantage" (p. 263). However, it is stated that as a small- to medium-sized agricultural trading country, Australia's potential to effect the Uruguay Round of negotiations is limited.

New Zealand's radical changes in its farm policy and the factors that have influenced political acceptability of the changes are discussed in Chapter 6 by Ross and Sheppard. Macroeconomic instruments, including exchange rate policies which have influenced agricultural trade, are examined. Moreover, government efforts to ease farmers' financial burdens that have been the outcome of the virtual elimination of agricultural subsidies in New Zealand are reviewed.

Sanderson and Mehra in chapter 7 bring the domestic policies of major traders (mainly the U.S. and the EC) together and review some of the theories of agricultural protection. They critically examine various policy tools. It is concluded that "the arguments for adopting forms of assistance that are more selective, less costly, and less market-distorting than across-the-board price supports will become more compelling" (p. 350).

Trends and projections in global food trends are discussed by Sanderson and Mehra in chapter 8. This chapter extensively uses graphs and tables to demonstrate commodity growth patterns in terms of production, consumption, trade, and prices. The role of developing countries in international trade is also discussed.

Global costs of protection and welfare gains from free trade are examined in chapter 9 by Blandford. This chapter compares the models that have attempted to measure the impact of trade liberalization on world and domestic prices, price variability, international trade, self-sufficiency rations, and social welfare. It provides a strong insight into the substantial costs generated by the existing policies in industrial countries and the difference free trade would make.

Josling, Sanderson, and Warley give an overview of the history of the General Agreement on Tariffs and Trade (GATT) and attempts through GATT to reduce agricultural protectionism. They discuss prospects for trade liberalization and various approaches that can be taken by negotiators in current and future GATT talks towards freer trade.

Although this book is well organized, it is limited in providing a theoretical background for the discussions contained in the book. Furthermore, its application is limited for readers who are interested in the role of developing countries and centrally planned economies in international agricultural trade. However, the volume provides extensive insight into the domestic and international policies of industrialized nations and problems created by their policies.

Shida Rastegari Henneberry
Oklahoma State University

Schmitz, Andrew, ed. *Free Trade and Agricultural Diversification: Canada and the United States.* Boulder CO: Westview Press, 1989, 366 pp., $42.50.

The prospect of a North American Free Trade Agreement has renewed interest among the agricultural economics profession in the agricultural provisions of the U.S.–Canada FTA. Although this agreement has limited provisions for agriculture, much research has been devoted to its possible production and trade effects.

Free Trade and Agricultural Diversification is a compendium of the work of several authors dealing with the possible effects of the U.S.–Canada Free Trade Agreement (FTA) and other policies influencing agricultural diversification and value-added activities in the Prairie Provinces of Canada. Most of the chapters are the result of a study undertaken by

the Economic Council of Canada on the future of the Prairie grain sector.

Schmitz's chapter 2, on "Agricultural Diversification Strategies: Canada and the United States," albeit mistitled because it deals primarily with trade disputes, provides a good background on the agricultural trade irritants that have erupted between the two countries in past years. One must remember that U.S.–Canada trade disputes in agriculture existed for several years prior to the U.S.–Canada FTA. The agreement resulted in greater focus placed on the disputes, witness the ongoing dispute over U.S. countervailing duties on Canadian pork imports.

Diversification of Prairie farm operations is examined in chapters 3 and 8 by Kerr and Brown. Both authors agree that the objective of diversification should not be producing different crops, livestock, or engaging in value-added processing per se but rather reducing the variability of income. Kerr supplies a good summary of the agricultural provisions under the U.S.–Canada FTA. His analysis finds that diversification is a limited option in the Prairie Provinces, given the high degree of price correlation that exists between the important Prairie commodities. Brown, also using correlation analysis, finds gains are minimal for diversifying within crops, but, unlike Kerr, he notes that "there are potential gains from crop farms diversifying into livestock enterprises provided their size is large enough" (p. 285). However, Brown uses net return of investment for crop and livestock operations as a correlation measure rather than price. Brown goes beyond Kerr's work by incorporating risk analysis through the construction of a risk-efficiency frontier chosen from a portfolio of crops, livestock, and off-farm investments.

Chapters 4 and 5 are devoted to covering value-added activities in Canada; Klein and Chase examine grain processing, beef, and biotechnology, while Carter, Karrenbrock, and Wilson focus on flour and beer markets. The chapters provide adequate industry profiles and explain how the FTA and other policies may affect these sectors. A revelation to this reviewer was the prevalence of licensing agreements existing between the largest Canadian and U.S. brewers that allow them to overcome barriers to trade. These licenses allow a Canadian brewer to produce and sell a U.S. beer after paying a royalty fee for the brand name and brewing information for the specific beer.

Chapters 6 and 7 look at irrigation technologies in the Prairies and the United States. Chapter 6 addresses diversification more directly than chapter 7, but Kulshreshtha contradicts Kerr's findings without presenting his own analysis. He mentions that Prairie crop farmers will diversify toward livestock production, "given the favorable economics of livestock enterprise" (p. 198).

The objective of chapter 9 is to examine the effects of farm programs on diversification within the United States. Just and Schmitz attempt to model these effects on wheat, feed grain, and soybean acreage through policy simulations under different scenarios. The chapter is fraught with equations and notation, making it the only chapter of the book which truly fails Schmitz's goal mentioned in the preface to be "readable by the general public" (p. ix).

Furtan, Fulton, and Rosaasen in chapter 10 provide a good description of the dichotomy of agricultural programs existing between the Prairie Provinces and Eastern Canada. This depicts the difficulty Canadian policy makers have in developing programs to encourage diversification that do not cause conflicts between regions. The authors provide a prime example of this tension by illustrating the effects of Canada's main transportation policy instrument for grains and oilseeds, the Western Grain Transportation Act.

Although the book's intended audience is the "general public," interested readers should have some background in Canadian agricultural policies because many of the authors presume prior knowledge of these policies. Outside of this, the majority of the text can be reasonably comprehended by masters degree students, with the exception of chapter 9.

Because the scope of the text is wide, I believe many readers will not find all chapters relevant. Given its cost, I could not recommend this book to general readers. The book's title implies that its subject matter will explore the relationship between the U.S.–Canada FTA and agricultural diversification; however, most of the chapters do not cover this implied relationship, if there is one. The text sometimes suffers from repetition between the chapters resulting from the overlap in material. I realize this can happen with a compendium. The proofreading of some chapters could have been improved given some glaring typographical errors. While I will not be as vociferous about this matter as was Goodloe's review, I will say it does detract from the professionalism of the text.

Mark Simone
Economic Research Service
U.S. Department of Agriculture

Reference

Goodloe, Carol. Review of Schmitz, Andrew, ed. *Free Trade and Agricultural Diversification: Canada and the United States*. Boulder CO: Westview Press, 1989. *J. Agr. Econ. Res.*, no. 4 (1990), pp. 39–40.

Singh, Inderjit. *The Great Ascent: The Rural Poor in South Asia.* Baltimore MD, and London: Johns Hopkins University Press, 1990, xiv + 444 pp., price unknown.

This book has had a very long gestation period. The research on which it is based had been under way for some time when a World Bank Staff Working Paper, *Small Farmers and the Landless in South Asia,* was issued in 1982, and three discussion papers were

published in 1988. The book was well worth waiting for. It is a concise, readable, and valuable account of four decades of agricultural development experience in Bangladesh, India, and Pakistan, with their combined populations of over one billion that are projected to reach a staggering 2.6 billion before stabilizing.

Singh examines a large body of relevant data and provides a very useful review and evaluation of much of the huge literature on rural development in South Asia. And that is accomplished without making it necessary for the reader to wade through a lengthy and tedious tome. The most significant statistical evidence is summarized in charts and text tables but with more detailed supporting data in forty-five tables. Those appendix tables plus the bibliography run to a hundred pages. (A small quibble. Given the meticulous attention to factual accuracy throughout the book, it is disconcerting that in the "Preface," Norman Borlaug's work is linked with maize instead of wheat.)

Chapters 2 and 3 "sketch the economic environment in which small farmers and the landless in South Asia seek their livelihood" (p. 95). Two factors which define the economic status of rural people—their access to land and to jobs—receive major attention throughout the book. Chapters 4 and 5 then "focus on the problems and prospects of raising the productivity of small farmers in the crucially important foodgrain sector and look at small farmers' access to credit and markets" (p. 96). Chapter 6 ("Noncrop Employment for the Rural Poor") is of great interest in emphasizing particularly the role of livestock and dairying in facilitating increases in productive employment and in income among small farmers and the landless and near landless.

Chapter 7 ("Rural Industrialization and Employment") reviews experience with rural public works programs and specialized poverty programs such as India's "Minimum Needs Program" as well as rural nonfarm economic activity. An important contribution of the book is the evidence that is marshalled concerning the strong linkages between agricultural growth and rural industrialization, especially with broadly based increases in farm incomes. The final chapter provides a balanced treatment of "Land Reform: The Missed Opportunity." Singh does make the common mistake of asserting that Taiwan's impressive agricultural development was "based initially on a very successful land reform" (p. 251). In fact, Taiwan's broad-based pattern of agricultural development was established during Japan's colonial rule: land ownership was highly skewed, but farm operational units were uniformly small because land was rented to tenants in small parcels (Johnston and Tomich). Singh recognizes the formidable political obstacles to redistributive land reform in South Asia, but he may well be realistic in concluding that "a land redistribution scheme that provides a minimum amount of land—say, a quarter to a half acre per household—is both desirable and feasible everywhere" (p. 308).

This careful and systematic examination of four decades of experience in South Asia suggests that the time may have arrived when development specialists have reached sufficient agreement to be able to offer consistent and reinforcing counsel to policy makers on the major issues of agricultural development. Certainly, there is now wide agreement "*that it is stagnation, not growth, that has brought impoverishment*" (p. 35; italics in original). To be sure, growth has often been accompanied by regional inequalities, and very small farmers and the landless have not benefited from the Green Revolution as much as would have been desirable—and feasible. Public policies and price distortions "have aided growth in advanced states and retarded it in others," in part because fewer public resources were left for infrastructural and other investments in poorer areas (p. 23).

Clearly, the crucial requirements are technological progress that facilitates widespread increases in productivity and growth in opportunities for productive employment that exceeds the rate of growth of the population of working age, thereby leading to a tightening of supply/demand conditions that pushes up returns to labor. Singh uses a dynamic model (developed with Richard Day) to project what would have happened to labor use in the Punjab if tractorization and other forms of mechanization had not occurred. On the assumption that an increased supply of draft animals and inmigration of labor fully replaced machines so that cropped area and cropping intensities were unchanged, total labor use without mechanization would have been much higher—134% higher in 1970 and an astounding 477% higher in 1980 (p. 191). The "without mechanization" scenario includes the assumption that even tubewells did not come on the scene, which seems extreme because tubewells were not so much a labor-saving substitution for Persian wheels as a new technology. Nonetheless, the comparison makes the important point that the Green Revolution could have had a much more powerful impact on the expansion of farm and nonfarm employment opportunities if subsidized credit and other policies had not encouraged an inappropriately capital-intensive expansion path.

There is little explicit attention in the book to the political economy issues of why governments adopt particular policies and reject others. Only occasionally does Singh fall into the trap of suggesting that admonition is all that is required to avoid unwise policies. In discussing the impact of new technologies on tenure systems he does declare: "Although technological progress should not be slowed, policymakers *must* find ways of ameliorating its impact on the poorer segments of the share-cropping population who will be rendered landless" (p. 287; italics added). But in considering why measures to enhance the security of tenure have in practice generally done more harm than good, he is properly skeptical in noting that such measures "would be desirable if good intentions could be turned into reality" (p. 294). Similarly, in discussing ways in which tenure changes can evolve to

facilitate changes "in the desirable direction of both efficiency and equity," Singh emphasizes that it will be through "power shifts and not through legislation in the name of simplistic abstractions, that the institution of tenancy will evolve" (p. 299).

Bruce F. Johnston
Stanford University

Reference

Johnston, Bruce F., and Thomas P. Tomich. "The Political Economy of Rural Development: Lessons from Asian Experience." *Conference on Directions and Strategies of Agricultural Development in the Asia-Pacific Region*, Taipei, 5–7 Jan. 1988. Institute of Economics, Academia Sinica.

Stout, B. A. *Handbook of Energy for World Agriculture*. London and New York: Elsevier, Applied Science, 1990, 504 pp., $135.00.

This is a superb book. Given current events, it is also particularly worthwhile to assess the current technological and economic state of agriculture on a worldwide stage as a supplier and user of energy. Stout is the editor of a series on energy in agriculture and here continues the high standard of those earlier editions. Agricultural economists and agricultural engineers interested in agricultural energy topics are Stout's prime audience.

The volume is ambitious in the breadth of information it wishes to convey. Basic definitions and concepts are developed for the novice. Chapters on energy use, flow, and management pay special attention to examples from developing countries and their different energy needs as well as the technologies used to address them. I suspect for the majority of readers the chapters on biomass, solar energy, wind energy, and hydropower will elicit the greatest attention. Here Stout displays his mastery of the subject by gracefully moving from agricultural engineering issues to those of the policy realm and economic assessment of the technologies. He provides a clear-eyed evaluation of each technology and often supplies a pro and con table of arguments to summarize their state of development. Solar heating, wind power, and hydropower are shown to have a role in the energy supply portfolio. Economic viability is, however, very site-specific. There are examples in California of cattle sharing their pastures with windmills producing environmentally clean electric power at costs comparable with conventional fuels. Especially in developing countries where renewable energy resources are plentiful, these technologies may prove to be economically and technically feasible. However, as always, Stout believes "a current, scientifically based feasibility study is absolutely essential to determine if a renewable energy system is a wise investment" (p. 441).

How about energy from biomass? Ethanol has proven itself as an octane booster. Stout notes that the technology is well established, but current research is needed to increase the process efficiency and lower the cost. To further that effort, the U.S. Departments of Agriculture and Energy are formalizing a coordinated effort to perform research to lower the cost of feedstock and conversion technologies as biofuels. Ethyl tertiary butyl ether (ETBE), an ethanol ether blend, not mentioned by Stout, is a recently developed fuel with potential. A virtue of ETBE is that the fuel reduces ozone pollution as well as carbon monoxide. The cost of production is less than ethanol proper, and the pipeline distribution system of the petroleum industry can be used, unlike ethanol, because ETBE does not attract water.

Stout also notes the potential for vegetable oils. Diesel fuel represents around one-fourth of the product from each barrel of crude. A vegetable oil substitute can now be produced that is almost indistinguishable from diesel fuel. The Clean Air Act also requires that diesel fuel have a sharply reduced sulfur content. Vegetable oil substitutes can meet the new specifications. Oilseeds, such as rape, crambe, sunflower, and others, may become major energy crops in the future as research reduces costs, which Stout indicates are currently almost twice as great as petroleum products. However, since the section was written and at this writing, recent price increases as a result of the Middle East disturbance have made vegetable oils competitive.

Global warming issues are not directly discussed in the book. However, certain topics mentioned are pertinent to addressing global warming. For example, the anaerobic digestion of animal waste can reduce methane emissions. There are now about 100 anaerobic digestors operating in the United States, and they can convert the waste to methane, which is then burned to generate electricity or hot water.

In sum, the continuing policy debate on national energy security issues and environmental concerns make this an important book for ready reference. Recommended.

Roger K. Conway
Office of Energy
U.S. Department of Agriculture

Tsakok, Isabelle. *Agricultural Price Policy: A Practitioner's Guide to Partial Equilibrium Analysis*. Ithaca NY: Cornell University Press, 1990, x + 305 pp., $54.50, $19.95 paper.

Agricultural price policy analysis in developing countries has been a growth industry in recent years as the philosophy of "getting prices right" rose to take temporary primacy among the panoply of development objectives espoused by aid agencies. This book, by a senior economist at the World Bank, is targeted at fledgling practitioners of agricultural price policy analysis. "The book was written primarily for officials who use their analytical insights to guide policymakers" (p. xv). Its goal is to provide them

with a set of basic tools to conduct such analysis. It is assumed that the reader has an understanding of the relevant economic theory, so there is little presentation of theoretical concepts. Although the title suggests that the book is limited to effects of agricultural price policy, in fact, the book (properly) includes a brief examination of exchange rate and factor price policies.

The book consists of two very different sections. The first 182 pages are divided into six chapters that focus on various methods of price policy analysis. The material in the chapters alternates between being broad and descriptive in nature to capture the "flavor" of price analysis, and detailed, with extended examples of the use of specific techniques. The remaining 108 pages are a series of appendices that cover a diverse assortment of topics, as described below.

After an introductory chapter, chapter 2 is an extended discussion of how one should get started in formulating the question at hand so that analysis can begin. It discusses how a researcher might begin to identify and collect data for the analysis and what kinds of initial data analysis should be done to guide further data collection and analysis efforts. It also contains an extended discussion of the various measures of exchange rate distortion that are used in agricultural price policy analysis.

Chapter 3, entitled "Coefficients of Production," begins the heart of the book. After a brief mention of efficiency considerations, it provides a lengthy discussion of nominal and effective protection coefficients and detailed examples of how they can be used. Chapter 4 is entitled "Coefficients of Comparative Advantage." The focus in this chapter is on domestic resource cost of foreign exchange (DRC) analysis. There is also a brief discussion of what the author calls the coefficient of net economic benefit (NEB), a concept that many readers will recognize as net social profitability (NSP). The first part of chapter 4 is devoted to a discussion of shadow pricing issues. This is followed by details on how the DRC is calculated conceptually and examples of actual calculations. All of the measures presented in chapters 3 and 4 focus on incentive effects and largely ignore market response to price changes.

Chapters 5 and 6 turn to the twin issues of market response to price changes through demand and supply price elasticities, and the resulting transfers among producers, consumers, and the government. Chapter 5 begins with a discussion of the perfectly competitive markets model and the concepts of producer and consumer surplus. A discussion of the differing responses of small and large open economies to price changes is followed by very general (and brief) discussions of topics such as the relevant time period, the need for separability in demand for theoretically correct aggregation, functional form, sample choice, and the basics of econometrics. The chapter ends with a discussion of practical considerations in finding appropriate elasticities and a table with ranges of elasticity estimates for selected commodities by country. The last chapter, 6, is primarily a series of examples on how to calculate various effects of imposition of an import or an export tax in a single commodity market. It ends with brief discussions of the effect of an overvalued exchange rate and multimarket effects of policy changes.

The second section of the book is a set of seven disparate appendices. The first provides a list of all the formulas presented in the text with their basic data requirements and a brief note on how each might be used. The first appendix also contains a list of national and international data sources. The second appendix, B, presents the derivation of and formulas for several of the price policy analysis tools in the case of a "large" country, i.e., one that has some influence over international prices. The third appendix, C, gives a detailed description of how to set up a spreadsheet to calculate the various coefficients. The fourth appendix, D, contains about fifteen pages of estimates of elasticities for various crops, countries, and time periods. The fifth appendix, E, takes the reader in great detail through calculations of the effects of a tariff and an export tax on various welfare and efficiency measures. The sixth appendix, F, is a note on the use and interpretation of price indices, including computation of terms of trade indices and real exchange rates. Finally, the last appendix is a review of the purchasing power parity approach to estimating the real exchange rate.

The book shows too clearly its roots as a manual for a course at the World Bank on agricultural price policy analysis. The appendices are not well integrated with the chapters. In the chapters, the combination of very detailed, step-by-step calculations with general statements about issues and approaches is sometimes confusing. Some of the confusion is a result of a poor choice of words or of editing. For example, on p. 134, the authors says "A uniform market price divides the area under the demand curve into two parts: the part above is the consumer surplus; the part below is total consumer expenditure." This statement is not exactly wrong, but it could have been said more clearly. On p. 139 the author states that "microeconomic theory generally deals with closed economies . . . ." I hope that is not a correct statement! At one point (p. 156), the arc price elasticity is defined so that its value depends on which of the two points is the initial point.

I also have some disagreements with the way factor market distortions are dealt with. For example, two types of nominal and effective protection coefficients are presented. One type, suggested as the more appropriate, includes a correction to the border price to account for a distorted exchange rate. However, the conventional use of nominal and effective protection coefficients is as measures of price distortion only (see Corden). If corrections for distortions in other markets are to be included, why limit them to the foreign exchange market? Another example is the definition of the shadow exchange rate to correct only for border interventions, not for differential rates of

inflation. Finally, there is no mention of more innovative techniques of presenting the combined effects of product and factor market distortions such as the policy analysis matrix (Monke and Pearson).

I have a more fundamental disagreement over the decision to include almost no discussion of the economic theory that underpins the tool kit presented. As the author states, "sound policy advice is an art, and there is no established methodology of bridging the gap between positive and normative economics . . ." (p. xvi). But a good price policy analyst (as well as a good artist) requires long years of training before bringing a product to the public. In the hands of the ill-trained, the tool kit provided by this book can be a dangerous instrument because it conveys the sense that agricultural price policy analysis can be undertaken merely by applying the appropriate formulas. The author includes several cautions about this danger, and mentions references to address it, but in the end decided to forego the theoretical presentation.

How do I plan to use the book? It will take a place on my reference shelf, as a place to look for formulas I have forgotten, as a source of some valuable data references, and as a place to send advanced undergraduate or graduate students in a food policy or cost benefit analysis class for some tips on how to get started or how to step through some calculations. But a budding agricultural price policy analyst should have some careful grounding in the underlying economic principles before using this book to learn the tools of the trade.

Gerald C. Nelson
University of Illinois

References

Corden, W. M. *The Theory of Protection*. Oxford: Oxford University Press, 1971.

Monke, Eric A., and Scott R. Pearson. *Policy Analysis Matrix for Agricultural Development*. Ithaca NY: Cornell University Press, 1989.

Tyagi, D. S. *Managing India's Food Economy: Problems and Alternatives*. New Delhi: Sage Publications, 1990, 240 pp., Rs. 165.

In their famous book *Famine 1975*, William and Paul Paddock had considered India to be a hopeless case, recommending that the principle of triage should be applied to food aid to India. Those who cannot be rescued should not be saved. India is now often described as a success case of foreign aid. In the immediate post-independence periods, i.e., in the 1950s and 1960s, slow growth in per capita food production combined with recurring droughts made nearly 40% of India's 400 odd million people vulnerable to chronic as well as temporary food shortages. Within less than three decades, India's vulnerability to droughts had been completely eliminated. Substantially larger numbers of people enjoyed physical and economic access to food, although problems of chronic hunger continue. In his book *Managing India's Food Economy*, D. S. Tyagi reviews these accomplishments and problems and makes several policy recommendations for improving the state of affairs, especially for bringing the high cost of the food policy under control.

Tyagi is eminently qualified to write this book. He is member secretary of India's influencial commission on Agricultural Costs and Prices. Tyagi has also published extensively on issues related to India's food policy and agricultural development. It is a sensible, well-researched, and cautious book that would be a useful guide for those in other developing countries interested in the issues of grain market liberalization, particularly from the viewpoint of its implications for accelerating agricultural growth; ensuring stability while achieving efficiency.

Tyagi discusses the elaborate government system of estimating supply, the role of the price commission in food policy, the system and agencies in charge of internal procurement, the role of international trade and of the public distribution system. The latter is a gigantic system which handles up to 20 million tons of grain a year out of a production of between 150 million tons to 160 million tons. Approximately 350,000 fair price shops, nearly 40% located in rural areas and each catering to about 2,000 people, distribute up to 18 million tons of grain a year. Tyagi describes how the food distribution system has helped avoid famines which took nearly 1.5 million lives in the notorious Bengal famine in 1943 and many subsequently. In Tyagi's view the system of price supports and government procurement also helped to accelerate the growth rate of food production made possible by high-yielding varieties of wheat and rice. Procurement prices of wheat and rice were fixed at a much higher level in 1967–68 than in 1962–63. This increased profitability and guaranteed return to farmers as the use of modern inputs had raised costs and increased the cash requirements of production. Real prices of wheat and rice, however, declined considerably in India since 1967–68. Tyagi shows that unit costs of production have declined even further, thanks to increased factor productivity as well as an array of input subsidies. Cost of the fertilizer subsidy alone amounted to Rs. 2.5 billion. There were also subsidies on irrigation water. Food policy also involved credit to traders for purchase of grain and a large number of interventions to increase employment, incomes, and demand for food by the poor people. For instance, in 1987–88, in addition to a variety of other national relief programs, 155,000 public works schemes alone created employment for 6.6 million persons per day.

Having reviewed these accomplishments, Tyagi turns to assess the impact and the cost of those policies. He asks three pertinent questions:

(*a*) Has the distribution in different states been proportional to the number of poor in the states?

(*b*) Have the quantities distributed gone to the poor?

(*c*) Have the share of supplies and price differences between public and privately traded commodities been large enough to compensate for the increase in open market prices?

Tyagi's answers to all three questions are largely in the negative. He shows that most of the supplies are allocated to urban areas, often in relatively better-off states where the politically powerful and vocal populations reside. Only a third of the supplies have gone to the really deserving. Tyagi also identifies other problems with the policy. For instance, wheat and rice rather than coarse grains consumed by the poor have received much of the support. Because of uniform procurement prices throughout the year the storage function has shifted largely to the public sector, increasing the cost to the treasury. The increased abrogation of responsibility for procurement by state governments has increased the cost of public distribution incurred by the central government through growing and unnecessary transshipment of grain across state boundaries. By 1987–88, the cost of subsidy for wheat had increased to 50% of the value of wheat, and in the case of rice it had increased from nil to 36%.

Tyagi argues that India's food self-sufficiency is now virtually guaranteed. Substantial diversification in food production and the consumption basket has occured. Thus, there is no more a case for control of the grain market on grounds of scarcity.

He argues for an alternative system of food management. This should include: targeted food subsidies for the benefit of the poor combined with release of grain at the wholesale level to stabilize prices in place of the current universal system of retail distribution, increased role of the private sector including futures trading, improved management of a smaller buffer stock and a greater reliance on international trade. Tyagi shows that the cost of buffer stocks has turned out to be 25% rather than 15% of the value of the grain as assumed originally, and overstocking as a result of poor intelligence on food production statistics has tended to result in larger stocks and excessive imports. It is clear from this well-articulated and meticulous analysis that the case for the new food policy in India is strong both on equity and efficiency grounds. Yet, Tyagi recommends only a 40% reliance on imports to begin with, and he does not make as strong a case for India undertaking to wipe out chronic hunger as it needs to do. India possesses the administrative capability but unfortunately lacks the political commitment to this important objective. Tyagi's book shows the snail's pace at which policy changes, notwithstanding the power of the evidence or the capability to implement a better policy.

Uma Lele
University of Florida

References

Paddock, William, and Paul Paddock. *Famine—1975*. London: Weidenfeld and Nicholson, 1968.

Lele, Uma, and Manmohan Agarwal. "Four Decades of Economic Development in India and the Role of External Assistance." *Transitions in Development*, ed. Uma Lele and Ijaz Nabi. San Francisco: ICS Press, 1991.

Necrology

Kenneth Leroy Bachman, U.S. Department of Agriculture and Food and Agricultural Organization of the United Nations, died November 1990, at the age of 77.

Gladys L. Baker, Economic Research Service, U.S. Department of Agriculture, died 1 January 1991, at the age of 80.

Dana G. Card, professor of agricultural economics at the University of Kentucky, died 14 August 1990, at the age of 92.

Selmer Engene, professor of agricultural economics, University of Minnesota, died 23 April 1990, at the age of 83.

Anthony Ferrise, professor of agricultural economics and state extension specialist for rural development, West Virginia University, died 6 November 1990, at the age of 59.

Gene A. Futrell, professor of economics and extension economist at Iowa State University, died 7 February 1991, at the age of 62.

John D. Helmberger, professor of agricultural and applied economics, University of Minnesota, died 10 November 1989, at the age of 74.

Virgil D. Kennedy, farm management specialist, University of Idaho, died 28 January 1991, at the age of 74.

Nathan Koenig, agricultural department official and former magazine editor, died 13 April 1991, at the age of 84.

Edwin H. Matzen, U.S. Department of Agriculture, died 31 May 1990, at the age of 79.

Allen B. Paul, Economic Research Service, U.S. Department of Agriculture, died 30 April 1991, at the age of 73.

Robert Raunikar, professor of agricultural economics, Georgia Agricultural Experiment Station, died 9 August 1990, at the age of 59.

Ronald R. Rhoade, Economic Research Service, U.S. Department of Agriculture, died 23 November 1990, at the age of 62.

Leroy Rottman, professor of agricultural economics, at the University of Missouri, died 19 May 1990, at the age of 72.

Chester W. Smith, Economist for the Northeast Dairy Cooperative Federation and the U.S. Department of Agriculture, died 1 March 1991.

Leland Spencer, professor of marketing, Cornell University, died 11 June 1990, at the age of 94.

Max M. Tharp, rural recreation specialist, U.S. Department of Agriculture, died 13 March 1989, at the age of 83.

Donald L. Vogelsang, former ACS employee, died 24 June 1990.

Frank J. Welch, executive vice president of the Tobacco Institute, died 28 April 1991, at the age of 88.

G. Burton Wood, Oregon State University economist, died 8 September 1990, at the age of 80.

Information on Submitting Manuscripts

1. **Cover letter.** In a cover letter, the author(s) must state (*a*) that the material in the manuscript has not been published, is not being published or considered for publication elsewhere, and will not be submitted for publication elsewhere unless rejected by the *Journal* editor or withdrawn by the author(s); (*b*) that the material in the manuscript, so far as the author(s) knows, does not infringe upon other published material protected by copyright; (*c*) that the employer of the author(s), if any, either does not assert an ownership interest in the manuscript or is willing to convey such interest to the American Agricultural Economics Association (AAEA); and (*d*) that submission of the manuscript gives the AAEA exclusive right to publish, to copyright, and to allow or to deny reproduction of it, in whole or in part. If the applicability of point (*a*) is unclear, the author(s) must explain.
2. **Author's identification.** To protect their anonymity in the review process, authors should not identify themselves in the manuscript. Attach a separate page including the names of the author(s) and appropriate biographical information, as well as the title of the manuscript. Include only the title on the first page of the text.
3. **Typing.** Double-space all material, including footnotes, tables, quotations, and references, on $8^1/_2$-by-11-inch standard weight white paper with margins on all sides of at least $1^1/_4$ inches.
4. **Style.** Follow *A Manual of Style* by the University of Chicago Press as well as previous issues of the *Journal*.
5. **Data and Documentation.** Authors are expected to document their data sources, models, and estimation procedures as thoroughly as possible, and to make data used in their analyses available to other researchers for replication purposes. If for legal or proprietary reasons, the data can not be made available to all potential users, this limitation should be noted. Submission of appendices, model documentation, and other supporting materials with the manuscript is acceptable in order to facilitate the review process.
6. **Mathematical notation.** Use only essential mathematical notation; it is costly to typeset and may limit the readership. Avoid using the same character for both superscripts and subscripts, using capital letters as superscripts or subscripts, and using overbars, tildes, carets, and other modifications of standard type. Asterisks, primes, and small English letter superscripts are suitable.
7. **Footnotes.** Number footnotes consecutively throughout the paper, not page by page. Type all footnotes, double-spaced, on a page following the article. Footnotes should be only explanatory and not for citations or for directing the reader to a particular work. This information can be incorporated into the text.
8. **References and citations.** Place all references, alphabetized by author, in a list at the end of the paper entitled "References." Only cited works should be included in the reference list. All citations should appear in the text and contain the author's name and page numbers, when necessary. Citations can be inserted parenthetically, e.g., (Doe) or (Doe, p. 5). Specify the date of publication if the same author appears more than once in the reference list, e.g., (Doe 1971, p. 5). If the author's name appears as part of a sentence, a parenthetical reference is unnecessary unless page numbers or a date are needed. A style sheet on references and citations is available from the editor.
9. **Tables.** Place each table on a separate page; double-space all material; omit vertical rules.
10. **Figures.** For accepted manuscripts camera-ready figures must be prepared using professional techniques that are suitable for photographic reproduction. Typescript is not suitable.
11. **Four copies.** Send four fully legible copies to the editor. All copies should be inspected for completeness and quality of reproduction.
12. **Abstract.** Instructions for the preparation of an abstract will be sent when a manuscript is accepted for publication.
13. **Page charge.** Major support for this ***Journal*** comes from page charges of $55 per printed page, or fraction thereof, payable by the supporting institution or granting agency. Payment does not affect acceptance, scheduling, or form of publication. Instructions for payment are sent with galley proofs.

American Agricultural Economics Association

Objective

The American Agricultural Economics Association (AAEA) seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy.

AAEA

—publishes the *American Journal of Agricultural Economics*, the *AAEA Newsletter*, *Choices*—The Magazine of Food, Farm, and Resource Issues, and, periodically, a *Handbook-Directory* of AAEA members;
—plans and conducts an annual meeting of the membership;
—sponsors awards for Distinguished Undergraduate Teaching, Distinguished Extension Programs, Distinguished Policy Contribution, Publication of Enduring Quality, Outstanding Journal Article, Quality of Communication, Quality of Research Discovery, Outstanding Master's Thesis, and Outstanding Ph.D. Dissertation;
—recognizes prominent agricultural economists as Fellows;
—operates the AAEA Employment Service for agricultural economists.

Membership and Subscriptions

AAEA is a professional society for agricultural economists and others who are interested in agricultural economics. A nonprofit organization, AAEA is committed to furthering knowledge about the economics of agriculture, rural communities, and natural resources.

Membership in the AAEA will bring you *Choices*, the *AJAE*, the *AAEA Newsletter*, and other occasional AAEA publications, permit you to use the AAEA Employment Service, and allows you to attend the annual meetings.

Calendar year dues are: $60, regular members; $30, senior (retired and 65) and junior (student) members; $90, family members; $170, industry members. Lifetime membership is available for members who are at least 55.

Subscription prices: *American Journal of Agricultural Economics*—$65 per year ($73 overseas); single copies, $14.50. *Choices*—The Magazine of Food, Farm, and Resource Issues—$32.50 per year ($52.50 overseas); single copies, $10. *AAEA Newsletter*—$12 per year ($17 overseas).

For further information about the American Agricultural Economics Association, contact the AAEA Business Office, 80 Heady Hall, Iowa State University, Ames, Iowa 50011-1070 (515-294-8700).

American Journal of Agricultural Economics

Volume 73 • *Number 5* • *December 1991*

6/5

In this issue: Proceedings from the annual meetings of the American Agricultural Economics Association held 4–7 August 1991 at Manhattan, Kansas

AAEA Annual Meeting
Baltimore, Maryland
9–12 August 1992

Editorial Communications

All manuscripts and editorial correspondence, except as noted below, should be addressed to:

Peter J. Barry, Editor
Department of Agricultural Economics
University of Illinois
305 Mumford Hall
1301 W. Gregory Drive
Urbana, Illinois 61801

Effective 1 February 1991, submissions of new manuscripts should be sent to: Steven T. Buccola and Richard M. Adams, Co-editors, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, OR 97331-3601.

Communications concerning book reviews and books submitted for announcement in the ***Journal*** should be sent to the book review editor: Otto Doering, Department of Agricultural Economics, Krannert Building, Purdue University, West Lafayette, IN 47907.

Editorial Policy

The purpose of the ***Journal*** is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged. The ***American Journal of Agricultural Economics*** (ISSN 0002-9092) is published monthly in February, May, August, November, and December by the American Agricultural Economics Association, 80 Heady Hall, Iowa State University, Ames, Iowa and printed by Edwards Brothers, Inc., Ann Arbor, MI. Second-class postage is paid at Ames, Iowa, and additional mailing offices. Postmaster: Send address changes to the American Journal of Agricultural Economics, 80 Heady Hall, Iowa State University, Ames, Iowa, 50011-1070.

Subscription

Subscription cost is $65 per year plus foreign postage; members receive copies as part of their membership fee of $60 per year.

American Journal of Agricultural Economics

Volume 73 • *Number 5* • *December 1991*

AAEA Fellows and Presidents

General Sessions

Invited Paper Sessions

Abstracts

AAEA Business

Index to Volume 73

Call for Papers: 75th Anniversary Issue of *AJAE*

In 1993, the *American Journal of Agricultural Economics* will celebrate its 75th anniversary. To commemorate 75 years of published research in agricultural, natural resource, and rural economics, AAEA will produce a special October 1993 issue of the *Journal*. The special issue will contain approximately ten essays on (*a*) the state and future of applied economics research methodology (philosophy of our science) and (*b*) the condition and likely future of the agricultural economics profession.

Format. Approximately three essays will be solicited from prominent scholars outside our profession; the remainder will be chosen competitively. Winners of the competitive paper slots will be selected by a ten-member committee appointed by the *AJAE* editorial board in consultation with past *AJAE* editors. Essays should be 15–30 double-spaced pages long. Published papers will be subject to the usual *Journal* page charge.

Topic areas. Sample topic areas include the following: Increased use of mathematics in research and reporting—benefits and problems. Does our profession have a complementary product mix? Prospects for multidisciplinary research in the face of increased specialization. Has the dream of rigorous hypothesis testing proven illusive? Extension's niche in increasingly commercial information markets. Future of agricultural economics in a nation of declining farm numbers.

Other sample topics are available from the *Journal* editors; these are suggestions only and are not exclusive. Acceptable topics do not include (*a*) specific research or policy issues (the subject of CHOICES' "Choices for the 21st Century" competition); (*b*) literature reviews or expositions of specific research methods.

Submission Format. Individuals wishing to compete for an essay slot should submit to the *AJAE* editors a 5–10 double-spaced-page summary paper. The summary should lay out clearly and in substantial detail the proposed theme, manner in which the theme will be developed, and principal conclusions.

Address submissions to Steve Buccola and Rich Adams, *AJAE* editors, Department of Agricultural and Resource Economics, Oregon State University, Ballard Hall 213, Corvallis OR 97331-3601. Questions may be directed to either editor at (503) 737-1410 or (503) 737-1435.

Timetable

1 February 1992.	Paper summaries are due from authors.
1 April 1992.	Winners of competitive paper slots are announced.
1 October 1992.	Preliminary paper drafts are due from authors.
1 February 1993.	Final paper drafts are due from authors.
1 May 1993.	Edited papers are sent to the printer.

AAEA Fellows and Presidents

Fellows, 1957–91

1957
John Donald Black
Thomas Nixon Carver
Joseph Stancliffe Davis
Garnet Wolsey Forster
Asher Hobson
Edwin Griswold Nourse
Theodore W. Schultz
Henry Charles Taylor
Frederick V. Waugh
Milburn Lincoln Wilson

1958
Mordecai J. B. Ezekiel
Oscar B. Jesness
William Irving Myers

1959
Harold Clayton M. Case
Oscar Clemen Stine

1960
Leonard Knight Elmhirst
Sherman Ellsworth Johnson

1961
Oris Vernon Wells
Ernest Charles Young

1962
Murray Reed Benedict
Hugh Bruce Price

1963
Raymond George Bressler, Jr.
Earl O. Heady

1964
Joseph Ackerman
Karl Brandt
Foster Floyd Elliott

1965
Bushrod Warren Allin
George Hubert Aull
Willard Wesley Cochrane

1966
J. Carroll Bottum
George E. Brandow
Forest Frank Hill

1967
D. Gale Johnson
William Hord Nicholls
Harry C. Trelogan

1968
John F. Booth
Maurice M. Kelso
Elmer Joseph Working

1969
Nathan M. Koffsky
James G. Mattox
Walter W. Wilcox

1970
Charles Edwin Bishop
Marion Clawson
Glenn Leroy Johnson

1971
D. Howard Doane
Don Paarlberg
Rainer Schickele

1972
Karl A. Fox

1973
Harold F. Breimyer
Kenneth H. Parsons
Lauren K. Soth

1974
Dale E. Hathaway
Vernon W. Ruttan
John F. Timmons

1975
S. V. Ciriacy-Wantrup
Geoffrey S. Shepherd
Holbrook Working

1976
Emery N. Castle
Arthur T. Mosher
Willard F. Mueller

1977
Lowell S. Hardin
Austin C. Hoffman
Sidney S. Hoos
Earl R. Swanson

1978
Chester B. Baker
James T. Bonnen
Richard A. King
Lawrence W. Witt

1979
Varden Fuller
Ruy Miller Paiva
Kenneth L. Robinson

1980
Harold O. Carter
Kenneth R. Farrell
John W. Mellor

1981
Ben C. French
Philip M. Raup
Samar R. Sen
James D. Shaffer

1982
Oscar R. Burt
R. J. Hildreth
Jimmye S. Hillman
George M. Kuznets

1983
Gordon A. King
Wayne D. Rasmussen
Bernard F. Stanton
Luther G. Tweeten

1984
Wallace Barr
Sylvia Lane
William G. Murray
G. Edward Schuh

1985
Harold G. Halcrow
Bruce F. Johnson
Andrew Schmitz
Harry R. Wellman

1986
John L. Dillon
Neil E. Harl
William E. Martin
Allen B. Paul

1987
Emerson M. Babb
C. Phillip Baumel
George E. Ladd
Daniel G. Sisler

1988
Paul L. Farris
Stanley R. Johnson
Alex F. McCalla
Clifton R. Wharton, Jr.

1989
Bruce L. Gardner
Joseph Havlicek, Jr.
Richard E. Just
William G. Tomek

1990

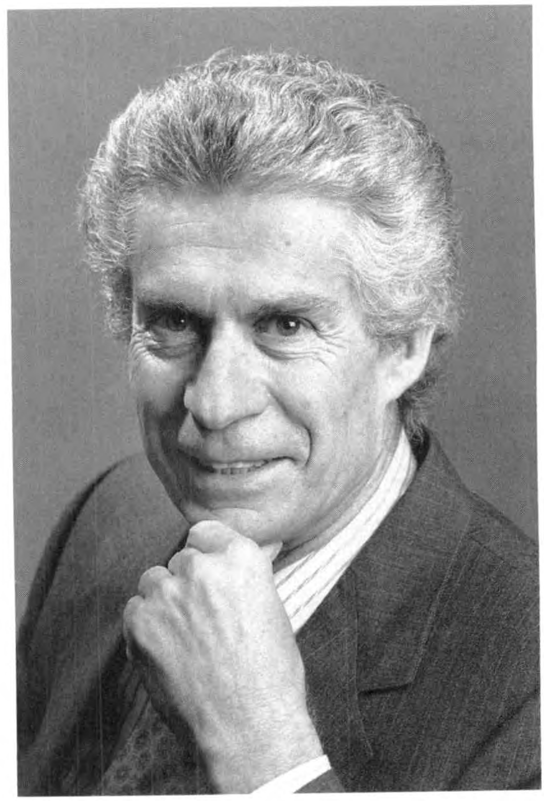
Walter P. Falcon
John E. Lee, Jr.
Gordon C. Rausser

1991

Alain de Janvry
Zvi Griliches
Yujiro Hayami
Lowell D. Hill

Alain de Janvry

1991 Fellow



Professor of Agricultural and Resource Economics, University of California, Berkeley.

Chairman, Department of Agricultural and Resource Economics, 1985–89, and Interdisciplinary Major in Development Studies, 1989–present, University of California, Berkeley.

Chairman, Giannini Foundation of Agricultural Economics, 1987–89.

AAEA Awards for Outstanding Ph.D. Theses and Best Published Research.

Ford Foundation project specialist in Argentina and advisor in Colombia and Chile.

Consultant to the United Nations Food and Agricultural Organization, the World Bank, the U.N. Development Program, the International Fund for Agricultural Development, the International Labor Office, the U.N. Joint Policy Consultative Group, the Inter-American Development Bank, the Consultative Group on International Agricultural Research, the International Food Policy Research Institute, the Economic Commission for Latin America, the Inter-American Institute for Cooperation on Agriculture, the Inter-American Foundation, USAID, the Rockefeller Foundation, the Agricultural Development Council, Winrock International, and the Sigma One Corporation.

Consultant to the governments of the Dominican Republic, India, Mexico, and Ecuador.

Visiting professor: University of Buenos Aires; Catholic University of Chile; Institut Agronomique et Vtrinaire Hassan II in Rabat, Morocco; University of Aix-en-Provence; Indian Agricultural Research Institute in Delhi; Institute of Economic Growth in Delhi; Cadre School in Dahlian, China; Northwest Frontier Province Agricultural University in Peshawar, Pakistan; and Centro per il Mezzogiorno in Portici, Italy. Advisory Committee, Rural Policy Program of the Aspen Institute.

Alain de Janvry is one of the leading agricultural development economists, a man of widely acknowledged international reputation, extensively cited for his seminal contributions to a broad array of fields, a major contributor to a large number of bilateral and international organizations on which his thinking has often had profound influence, and, on the Berkeley campus, a recognized leader in international development and a much appreciated teacher and former department chairman.

Alain de Janvry was born in France and educated in France and Spain in the fields of mathematics and philosophy. He graduated from the Institut National Agronomique in Paris with an engineer degree and a specialization in agricultural economics. He came to the University of California at Berkeley as a Fulbright Fellow and

received an M.S. in agricultural economics and an M.A. in statistics. His encounter with Professor George Kuznets and his close association with this distinguished professor induced him to remain at Berkeley for the Ph.D. degree. Under Professor Kuznets, he wrote an AAEA award winning dissertation in demand analysis and soon afterward joined the faculty of the Department of Agricultural and Resource Economics at Berkeley where he has developed his career to this day.

His research spans a remarkable breadth of fields, and there are indeed few areas in agricultural economics where he has not made significant contributions. His publications include more than 150 articles and several books and monographs. His research has, in general, been guided by a deep concern with poverty, the welfare of rural households, and the quest for program designs and policy alternatives aimed at reducing the incidence of poverty. While he has systematically explored these subjects from the level of grassroot organizations to that of macropolicy, he has always searched for new theories and concepts, strong empiricism, and focused on the interactions between efficiency, welfare, and the forces of the political economy. He has been a pioneer in the field of the political economy of reform, combining the rigors of mathematical neoclassical analysis with insights derived from classical economics. He has the unusual ability to trespass across disciplines, with the result that political scientists, sociologists, and anthropologists have commonly called him one of their own. That this work has also had a visible impact on our profession is reflected by the fact that he is one of the most frequently cited agricultural economists.

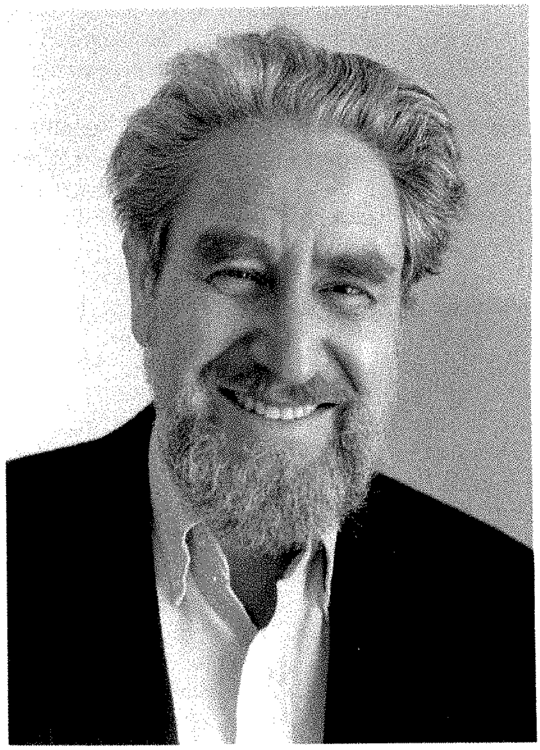
His research has opened new perspectives in the fields of demand analysis, behavior toward risk, technological innovations, land reform, rural development, price policies in general equilibrium models, equitable approaches to stabilization and adjustment, conflict management between aid and trade, household behavior under market failure, classical and neoclassical political economy, the theory of agrarian institutions, and environmental management in the context of rural development. The scope of his research is thus truly unusual as it spans from micro- to macroeconomics and from the roles of markets to those of civil institutions and the state.

The leadership which Alain de Janvry has exercised in the field of international agricultural development is plainly visible through his extraordinary volume of publications and the attention they are receiving, his continued involvement with many international and bilateral organizations, his administrative roles at the University of California and in the profession, and the many students he has taught and placed in key professional positions. He has been a widely sought and unselfish teacher on the Berkeley campus and throughout the world. And he has been successful in directly extending the results of even his most theoretical research to policy makers and development agencies, making him an effective man of action at the same time as a creative scholar.

Zvi Griliches

1991 Fellow

Paul M. Warburg Professor of Economics, Harvard University, 1987–present.
Taussig Research Professor, Harvard University, 1983–84.
Chairman, Department of Economics, Harvard University, 1980–83.
Nathaniel Ropes Professor of Political Economy, Harvard University, 1979–87.
Professor, Department of Economics, Harvard University, 1969–present.
Professor, Department of Economics, University of Chicago, 1964–69; associate professor, 1960–64; assistant professor, 1956–59.
Visiting appointments: Max Bogen Visiting Professor of Economics, Hebrew University, Jerusalem, spring 1987; visiting professor, Ecole des Hautes Etudes en Sciences Sociales, Paris, 1984; Einstein Visiting Professor, Hebrew University, Jerusalem, spring 1984; visiting fellow, Institute for Advanced Studies, Hebrew University, Jerusalem, 1977–78; visiting professor, Hebrew University, Jerusalem, 1972; visiting professor, Econometric Institute, Netherlands School of Economics, Rotterdam and Hebrew University, Jerusalem, 1963–64; research associate, National Bureau of Economic Research, 1959–60, and at Economics Research Center, Catholic University, Santiago, Chile, summer 1959.
American Economics Association, vice-president, 1984; executive committee, 1978–81.
Econometric Society: president, 1975; vice-president, 1973–74.
Coeditor *Econometrica*, 1969–77.
Awarded John Bates Clark Medal by the American Economic Association, 1965.



Elected Fellow of the American Association for the Advancement of Science, 1966, the American Statistical Association, 1965, and the Econometric Society, 1964.
Elected to the National Academy of Sciences, 1975, to the American Academy of Arts and Sciences, 1965, and to the Conference on Research in Income and Wealth, 1962.
Recipient of the American Farm Economic Association's awards of merit for best published research in 1958, 1959, 1961, and 1965.

Zvi Griliches, Paul M. Warburg Professor of Economics, Harvard University, has made an outstanding, long-term contribution to agricultural economics. He has attained an internationally renowned reputation for his research on the topics of generation and adoption of new agricultural technology, the measurement of social returns to agricultural research, and the theory and measurement of input quantities and productivity growth in agriculture. In addition, he has been an outstanding teacher and developer of research skills in graduate students in agricultural economics.

The esteem and respect for Griliches is shared widely in the profession. He has been a creative, prolific researcher and contributed very

importantly to the literature of agricultural economics. For example, the first successful effort to rigorously measure the rates of return to technical change in agriculture was his 1957 dissertation, "Hybrid Corn: An Exploration in the Economics of Technical Change." All subsequent work on returns to research has followed his pathbreaking contributions. The study on hybrid corn was followed by a series of studies on the contributions of research, extension, and education to agricultural supply and productivity growth. This body of research was recognized by four published research awards by the American Farm Economic Association.

Griliches has an outstanding research record that is highly cited. A very useful collection of his pathbreaking research contributions appears in his latest book, *Technology, Education and Productivity: Essays in Applied Econometrics* (Basil Blackwell, 1988). Roughly half of the chapters deal with the agricultural sector of the economy, and these papers have had a major influence on subsequent research in agricultural economics. They serve to document Griliches' work and provide a record of his seminal empirical studies of economic growth. Griliches' hybrid corn study illustrates how to measure technology adoption and indicates how economic forces stimulate the production and diffusion of this technology. The rate-of-return calculations used so widely in the agricultural economics literature can be traced to the hybrid corn study, where the basic supply function shift and the consumers and producers surplus measurements were established.

The "Social Science Citation Index" provides a useful reference to the enduring importance of Griliches' research. Over the last decade his seminal articles, including "Hybrid Corn: An Exploration in the Economics of Technical Change," *Econometrica* (1957); "The Sources of Measured Productivity Growth: United States Agriculture, 1940–60," *J. Polit. Econ.* (1963); and "Research Expenditures, Education and the Aggregate Agricultural Production Function," *Agr. Econ. Res.* (1964), continue to be cited frequently. Equally impressive is his total citation count, averaging more than 150 per year.

In addition to the earlier direct contribution to the agricultural economics literature, Griliches continues to make an outstanding contribution to agricultural economics through his later research on general issues associated with technical change and the measurement of productivity growth. His continuing research on productivity measurement, the economics of education, the economics of research and development, and index number theory is of major importance for research in agricultural economics. And his recent work continues to be widely cited by agricultural economists.

Griliches has also been an outstanding teacher and developer of professionals in the agricultural economics arena. His concerns for sound theoretical foundations underpinning all economic analyses, use of simple but appropriate econometric techniques, and careful construction of empirical measures of variables have been instilled in all of his students and close associates. His former students include current leading agricultural economists and notable econometricians.

The contributions of Griliches to research in agricultural economics are pioneering, substantive, and enduring. He has made and continues to make a tremendous contribution to the profession through his own research and the research and leadership of his former students.

Yujiro Hayami

1991 Fellow

Japan Foundation Visiting Professor and Taisho Fellow, Economic Growth Center, Yale University, spring 1991.
Professor of Economics, School of International Politics, Economics, and Business, Aoyama Hakuin University, 1986–present.
Professor of Economics, 1972–86; associate professor, 1966–72, and University Council member, 1971–81 and 1983–85, Tokyo Metropolitan University.
Agricultural economist, International Rice Research Institute, Philippines, 1974–76.
Visiting professor, Department of Economics, University of the Philippines, 1974–76.
Visiting associate professor, Department of Agricultural Economics, University of Minnesota, 1968–70.
Research Associate, the National Research Institute of Agricultural Economics, Japan Ministry of Agriculture and Forestry, 1955–66.
Editorial Council member, *American Journal of Agricultural Economics*, 1972–74, 1984–86; *Journal of Japan Society of Agricultural Economics*, 1975–77; *Agricultural Economics*, 1986–present.
Awards: AAEA Outstanding published research award, 1971; Outstanding Journal Article award, 1976, 1978; Publication of Enduring Quality, 1985. Agricultural Economics Society of Japan Distinguished Research Award, 1967; Institute of Developing Economics Outstanding Article award, 1968; Nikkei Shinbun Economics Book award, 1971. The National Institute for Research Advancement, Tohata Memorial Award for Distinguished Policy Research, 1987.

Yujiro Hayami, born in 1932, was one of the first Japanese to earn a U.S. Ph.D. in agricultural economics after World War II (Iowa State, 1960). He began his professional career in the National Research Institute of Agricultural Economics in Japan, followed by two decades' service at the Tokyo Metropolitan University. He recently moved to Aoyama-Gakuin University. He has also served as visiting professor at the University of Minnesota and as an economist with the International Rice Research Institute in the Philippines. He served on the Editorial Council for the *American Journal of Agricultural Economics* in 1972–74 and 1984–86. He has avoided administrative appointments throughout his career.

Hayami has advanced knowledge in three important areas. The first was to identify the stylized facts and working mechanisms of agricultural development through both historical and intercountry comparative analysis. His book with Vernon W. Ruttan, *Agricultural Development: An International Perspective*, was the major product of this effort. The main contribution of the book was to advance and test the induced innovation model of agricultural development. His second major contribution was based on a series of village-level studies in the Philippines

and Indonesia. These studies are reported in *Asian Village Economy at the Crossroads* (with Masao Kikuchi) and a forthcoming book on peasants' marketing and processing activities in Indonesia. They shed new light on the institutional and organizational structure of peasantry in Asia and confirmed the power of the induced innovation model to interpret institutional change. Hayami's third contribution in the area of political economy includes *The Political Economy of Agricultural Protection* (with Kym Anderson) and a recently published book outlining a new theory of land reform drawing on Philippine experience, entitled *Toward an Alternative Land Reform Paradigm* (with Agnes Quisumbing and Lourdes Adriano).

A common thread connecting these three research areas is his keen interest in the innovation inducement mechanism operating through interactions among resource endowments, technology, and institutions.

Lowell D. Hill

1991 Fellow

L. J. Norton Professor of Agricultural Marketing, University of Illinois, 1977–present.

Editorial Council, *American Journal of Agricultural Economics,* 1980–83; AAEA Awards Committee, Publication of Enduring Quality, member, 1978–80, 1986–88, chairman, 1980, 1988.

U.S. Department of Energy Food Advisory Committee, 1978–80; National Grain Quality Task Force, 1986–present.

Consultant to U.S. General Accounting Office; Office of Technology Assessment, U.S. Congress; Office of Transportation, U.S. Department of Agriculture; Agency for International Development; World Bank, Food and Agriculture Organization; U.S. Feed Grains Council.

Awards: AAEA Award for Distinguished Extension Program, 1989; Award for Quality of Communication, 1988; Honorable Mention, Quality of Communication, 1988; Award for Distinguished Policy Contributions, 1988; Award for Quality of Communication, 1980. USDA Distinguished Service Award, 1989; Paul Funk Award for Outstanding Service to Agriculture, 1979; Senior Faculty Award for Excellence in Research, University of Illinois, 1991.

Author of *Grain Grades and Standards: Historical Issues Shaping the Future,* University of Illinois Press, 1990.

Lowell D. Hill has distinguished himself internationally through his rigorous analysis of practical economic problems and his exceptional skills in communicating his findings to implementers of change.

His depth of understanding of the many disciplines involved in improving grain quality has enabled him to integrate the research results of physical scientists into economic models. Hill's pioneering research on causes of grain quality loss in international markets generated controversy; however, the strength of his economic concepts and his communication ability (recognized by three AAEA Quality of Communication awards) prevailed. Opponents gradually became supporters for change under the irrefutable logic of Hill's research and persistent application of economic principles. The 1986 Grain Quality Improvement Act and the 1985 and 1990 farm bills included sections drawn directly from Hill's research.

The importance of his contributions has been recognized repeatedly: by the AAEA with two awards and one honorable mention for Quality of Communication in 1980 and 1988; Distinguished Policy Contribution, 1988; Distinguished Extension Program, 1989; by the U.S. Department of Agriculture with its Distinguished Service Award in 1989 and by the University of Illinois with an endowed chair in 1977, Service to Agriculture in 1979, and Senior Award for Research in 1991. He has received numerous other awards and recognition from industry and producer groups.

Born in Iowa in 1930, Hill received a B.S. degree from Iowa State University. He taught

vocational agriculture to veteran's classes and operated a grain-livestock farm from 1955–59. He then moved to Michigan State University for his M.S. and Ph.D. degrees.

Hill is a stimulating teacher and speaker and a prolific author. Although his program spans the globe, he always finds time to work with students and farmers, assist colleagues, host international visitors, and advise firms on marketing strategies. He has published more than 550 papers, including the landmark book, *Grain Grades and Standards: Historical Issues Shaping the Future*. He has edited four major books, and has authored or co-authored eighteen chapters in books, forty-five refereed journal articles, and fifty-five experiment station bulletins.

There is no question that Hill has made a significant personal and professional contribution to agricultural economics, the American Agricultural Economics Association and to the agricultural sector. Few others have left such a scholarly wake through the generation, publication, and application of knowledge. His program has left an indelible mark on students, agricultural policy, the grain industry, and the profession.

Presidents, 1910–92

1910–12
William J. Spillman

1913
George F. Warren

1914
Daniel H. Otis

1915
Andrew Boss

1916
Harcourt A. Morgan

1917
Henry W. Jeffers

1918
George A. Billings

1919
John R. Fain

1920
Henry C. Taylor

1921
Walter F. Handschin

1922
Benjamin H. Hibbard

1923
Thomas P. Cooper

1924
Edwin G. Nourse

1925
Milburn L. Wilson

1926
Thomas N. Carver

1927
John I. Falconer

1928
Lewis C. Gray

1929
H. E. Erdman

1930
Harold C. M. Case

1931
Oscar C. Stine

1932
John D. Black

1933
Howard R. Tolley

1934
William I. Meyers

1935
Waldo E. Grimes

1936
Joseph S. Davis

1937
Oscar B. Jesness

1938
Ernest C. Young

1939
Irving G. Davis
Foster F. Elliott

1940
Hugh B. Price

1941
Murray R. Benedict

1942
George S. Wehrwein

1943
Sherman E. Johnson

1944
Eric Englund

1945
Lawrence J. Norton

1946
Frederic V. Waugh

1947
Asher Hobson

1948
William G. Murray

1949
Oris V. Wells

1950
Warren C. Waite

1951
Forrest F. Hill

1952
George H. Aull

1953
Harry R. Wellman

1954
Thomas K. Cowden

1955
Joseph Ackerman

1956
Karl Brandt

1957
H. Books James

1958
Harry C. Trelogan

1959
Raymond G. Bressler, Jr.

1960
Willard W. Cochrane

1961
William H. Nicholls

1962
Bushrod W. Allin

1963
George E. Brandow

1964
Lowell S. Hardin

1965
D. Gale Johnson

1966
Kenneth L. Bachman

1967
Lawrence W. Witt

1968
C. E. Bishop

1969
Harold F. Breimyer

1970
Dale E. Hathaway

1971
Jimmye S. Hillman

1972
Vernon W. Ruttan

1973
Emery N. Castle

1974
Kenneth R. Tefertiller

1975
James Nielson

1976
James T. Bonnen

1977
Kenneth R. Farrell

1978
R. J. Hildreth

1979
Bernard F. Stanton

1980
Richard A. King

1981
Luther G. Tweeten

1982
G. Edward Schuh

1983
Leo C. Polopolus

1984
Neil E. Harl

1985
C. B. Baker

1986
William G. Tomek

1987
Joseph Havlicek, Jr.

1988
Daniel I. Padberg

1989
Lester V. Manderscheid

1990
Sandra S. Batie

1991
Warren E. Johnston

1992
Bruce R. Beattie

Bruce R. Beattie

1991–92 President

Professor and Head, Department of Agricultural Economics, University of Arizona, 1990 to present.
Professor of agricultural economics, Montana State University, 1979–90.
Head of agricultural economics and economics, Montana State University, 1979–84.
Associate professor of agricultural economics, Texas A&M University, 1974–79.
Associate professor of agricultural economics, Iowa State University, 1973–74.
Assistant professor of agricultural economics, University of Kentucky, 1969–73.
Director of Western Agricultural Economics Association, 1976–78.
President of Western Agricultural Economics Association, 1981–82.
Associate editor of *American Journal of Agricultural Economics,* 1986–91.

Bruce R. Beattie was born and raised on a small wheat and cattle ranch in central Montana. His grammar school education was completed in a one-room rural school near Hilger, Montana. (During his last two years, the student body consisted of Bruce, his sister, and his adopted brother). As a youth he was active in 4-H and FFA. Beattie's B.S. and M.S. degrees in agricultural economics were earned in 1963 and 1964 from Montana State University. His Ph.D, under the direction of William G. Brown and Emery N. Castle, was awarded from Oregon State University in 1970.

Beattie's first faculty position was at the University of Kentucky. He subsequently served on the faculty at Iowa State University, Texas A&M University, Montana State University, and the University of Arizona. At Montana State and now at Arizona, Beattie also served(s) as head of department.

Beattie's teaching/research interests include natural resource economics, production economics, and microeconomic principles. He is an accomplished and dedicated teacher—an occupation he thoroughly enjoys. Several of his graduate students have been recognized through the thesis and dissertation awards programs of AAEA and WAEA. His love of teaching and enthusiasm for the beauty and explanatory power of economic reasoning is reflected in Professor Beattie's considerable effort in writing for students and lay audiences. Beattie has received published research awards from both the American and Western Agricultural Economics Associations for his work in the area of water economics, specifically the demand for water in

agricultural and urban residential uses. In 1989, he received the WAEA's extension program award for his participation in an educational program concerning state-level public finance issues. Recently, Beattie has taken to writing about university administration and the academic enterprise; he is frequently asked to serve as a CSRS review team panelist and guest lecturer on these topics. Beattie has been very active in university service and in service to his profession.

Some Almost-Ideal Remedies for Healing Land Grant Universities

Bruce R. Beattie

This paper follows up on the "Land Grant University Revitalization Debate" so forcefully and eloquently led by Schuh, Bonnen, and others. The paper offers some small steps that might be taken (little things that might be done) by way of internal institutional reform to enhance the prospects for sustainability and contribution of the land grant tradition in the twenty-first century.

Two topics are addressed in the spirit of institutional reform: (*a*) fixing administrative structure, titles, and responsibility consistent with a collegial environment of individual faculty entrepreneurs, i.e., a university environment, and (*b*) fine-tuning faculty incentive mechanisms, i.e., faculty evaluation processes for annual merit-salary increments and promotion and tenure. The centrality and preeminence of the single, coherent mission of educating resident and nonresident students through teaching/learning/discovery is an underlying subtheme. The general pedagogical strategy is to discuss "the way it is," followed by "the way it ought to be—an ideal," and concluding with "a way it might possibly be—an almost ideal." That is, the plan is to conclude each section with suggestions for reform that are hopefully doable—that move us in a positive direction and that stand some chance of gaining acceptance within the academic community. A modest number of ideas are offered that might lead us from where we are toward greater service to society given the fundamental nature and purpose of a university.

Setting the Stage

Certainly prominent among those calling attention to apparent problems in the direction and priorities of our land grant universities have been Schuh and Bonnen. In his widely read and cited piece in *CHOICES*, Schuh argues that our land grant universities have "lost their way" and are in serious need of "revitalization." Among the symptoms of malaise he notes are faculties introverted in their disciplines, publishing for professional peers to the disadvantage of applied work, and consulting for the highest paying firm or agency in lieu of public service. Schuh calls for a recommitment to the tripartite mission of teaching, research, and extension and to an institutional mission of contributing to the solution of society's problems.

Schuh challenges us to (*a*) capitalize on what we have learned about agricultural development, specifically, to invest more in human capital formation (I take that to mean a higher priority on our teaching functions); (*b*) respond to the changed economics of education, i.e., recognize the opportunity cost of students and adapt our teaching/training programs accordingly; (*c*) train and educate students for the international economy; (*d*) contribute to the design of institutions; (*e*) span the ever-widening gap between the frontier of knowledge and the problems of society; and (*f*) give university administrators more authority. Watts and I expressed concern about the validity of Schuh's allegation that the applied gap between the frontier of knowledge and societal problems was not being addressed, and we (and others) wrote in strong opposition to the proposition that university administrators be granted more authority (Beattie and Watts, Bromley, Smith). Neither of these two issues need be recounted here. Suffice it to say that most, if not all, of what Schuh had to tell us is

---

Presidential address.

Bruce R. Beattie is a professor and head of the Department of Agricultural Economics at the University of Arizona.

The author makes no particular claim of originality or great insight. The ideas conveyed in this paper are due, in part, to the influence and writings of many economists. Prominent among those are Emery Castle, Ken Farrell (and coauthors), Al Halter, Dennis Henderson, Marc Johnson, Warren Johnston, Dan Padberg, Ed Schuh, Richard Stroup, and, especially, Myles Watts. (The author's debt to Watts is sufficiently great that if it were appropriate to coauthor a presidential address, he would qualify in spades.) To all these people, the usual caveat applies—and with force, for none of them except Watts had an opportunity to see the paper prior to printing. Unfortunately for the author, none of these people can be held accountable for misinterpretation of, or injury caused to, their otherwise good idea(s).

worthy of our serious consideration and corrective action. I find Schuh's first four tasks and giving even greater attention to "spanning the ever-widening gap" compelling indeed.

Bonnen, in his 1986 AAEA Fellows Address, lends support to a number of Schuh's themes. Bonnen, like so many others, is concerned that the reward structure of most contemporary land grant universities undervalues applied subject-matter and problem-solving research relative to disciplinary research. He is concerned about the basis for effective extension education and problem solving, and by implication a penalizing of those who do empirical work.

Harold Enarson, a past president of The Ohio State University and senior advisor to the Western Interstate Commission on Higher Education, draws significantly from Schuh in expressing his concerns. He notes that many land grant universities, along with the best of the other state and private universities, have become "premier national institutions," attaining the status of so-called research universities. Enarson is concerned whether land grants universities can embrace the research university model and remain faithful to the land grant mission.

As these concerns are played out, it occurs to me that our land grant institutions are engaged in a war involving two closely related yet distinguishable battlefields. There is the external war for the hearts, minds, and tax dollars of the citizens that support and sustain us. It seems clear that this external war is on the minds of many, e.g., Hildreth, Enarson, McDowell and others. Yet, clearly the external war is intimately connected to a battle within the university about what is going to count, what we are about, and who are going to be the principal players. It is this internal battle to which most of my remarks are directed. It is a battle of particular importance to our colleges of agriculture, and one, in my view, that we must win if we have any hope of success in the larger struggle.

To put it rather directly and perhaps a bit harshly, the internal war has to do with the perceived irrelevance and inferior scholarship of many, if not most, of the more applied professional programs within our land grants—agriculture being a prime example. It has to do with the matter of the relative importance of teaching or human capital building *vis-à-vis* new knowledge discovery of initial primary interest to ourselves and our peers, and to the legitimacy and scholarly quality of the extension mission. It is my view that if we applied-types can better position ourselves within the land grant university, then our and the university's chances of success in the external war and opportunities for greater social service are decidedly enhanced. Those of us in the application business and in the professional schools are a minority. The sooner we recognize that and begin to compete with first-class scholarship and a mind-set in concert with academia generally, the sooner we will be able to win over the "rest of the university" and get on with the important work of enhancing the status of resident and nonresident teaching and obtaining recognition for the high social value of rigorous applied knowledge. For colleges of agriculture, getting our minds in concert involves nothing more than modifying our language and administrative structures to something to which the rest of the university can understand and relate.

Enough said by way of background. To be sure many among us, perhaps even a majority, believe there are problems of priority, of lost mission, of undervaluation of teaching (including extension). The voices of these individuals have not fallen on deaf ears. Probably every land grant university is presently giving serious discussion and attention to these matters, especially to the alleged undervaluation of excellence in teaching. With the aim of redressing some of the perceived maladies, this paper offers some ideas for rethinking how we view our role, how we administer and govern ourselves and our programs, how we might modify our incentives structure and evaluation processes, and how we might adopt a heightened view of teaching (both resident and nonresident varieties).

Fixing Administrative Structure, Titles, and Responsibility

In my humble opinion, the administrative structures of most of our land grant universities are, to put it mildly, a mess. It is little wonder that many of us find ourselves concerned about the lack of coherence of our academic programs, about the lack of integration of research and teaching, including nonresident teaching (extension), about the apparent low priority of teaching generally, and a number of other maladies. Consider a simplified organization chart for the typical land grant university (fig. 1). Amazing; and, mind you, this is simplified! I have not bothered to add in the complexities of that whole army of so-called academic professionals that oftentimes, I get the feeling, run the university—the offices of the registrar, of admissions,

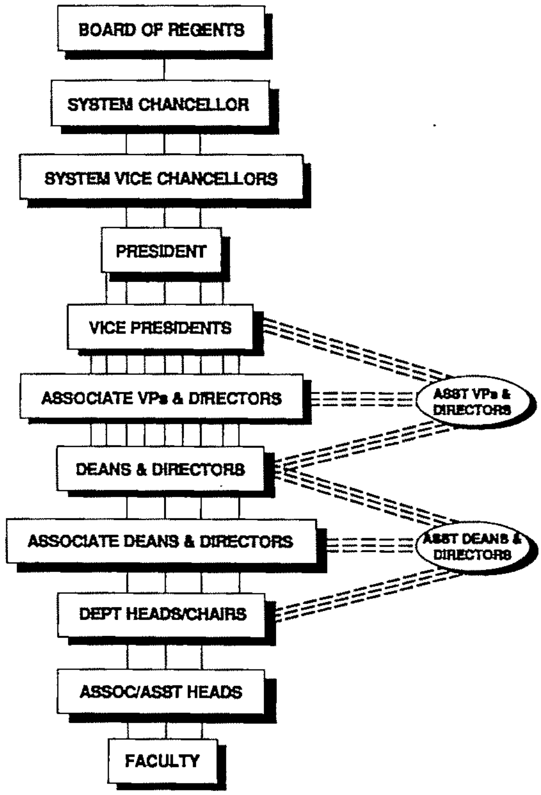


Figure 1. A simplified typical university organization chart

of affirmative action, of student affairs and services, of facilities planning and management, of intercollegiate athletics, and so on. Nor does my schematic include all the invisible curved lines that connect every "lower level" with each and every "upper level." Actually, these omitted (invisible) lines are among the most important. Also missing from my chart is the vast array/network of interdisciplinary institutes, centers, and specialized study programs (for every imaginable topic) that permeate and infest so many land grant universities these days. (But that is another topic best left for another time. Suffice it to say, my attitude about such creatures is not unlike Stigler's. I recommend his essay on "Specialism: A Dissenting Opinion" [pp. 9–16] for your enjoyment.) Finally, I have not included the sometimes lightening-bolt-like lines that connect the state legislature and governor's offices to various levels of the official organization chart.

Notwithstanding these important omissions, there are sufficient serious problems of structure and title on this simplified organization chart (fig. 1) to make one's head swim. To begin, the solid vertical lines are presumed and sometimes actual lines of authority. The dashed lines denote staff functions; unfortunately, they are most often staffed with Ph.D.s and may or may not have significant duties, responsibility, or authority. The first problem that should be apparent to almost everyone is that there are far too many layers of administration above those that carry out the principal purposes and valuable work of the university, viz., the faculty. Not only is the overburden enormously expensive and cumbersome, it is often obstructive and not always prone to good judgment. It is certainly not compatible with fostering creativity. The expense of excessive administrative overburden is especially noticeable/painful in our "smaller" land grant universities. Such institutions, even those with fewer than 10,000 to 15,000 students, seem bound and determined to emulate their big research-university brethren in all ways, good and bad. The need for smaller universities to streamline and reduce their administrative structure seems particularly manifest.

A second problem with the chart (fig. 1) for many members of academia is the curious title of "director" that appears here and there, especially in colleges of agriculture. Can you imagine the reaction of an historian, a philosopher, a mathematician, a physicist, or a professor of modern languages to the very idea that there might be someone (especially an administrator) who somehow "directs" the programs of individual faculty members or some collective of same? The very idea is foreign and repugnant to most of academia. And it should be to us as well. But even if it is not, we, in colleges of agriculture, should shed ourselves of such administrative titles in the interest of opening up the lines of communication with the rest of the university if we wish to push successfully the case for the importance of extended education and applied research.

To pursue these ideas further consider figure 2, a revised version of figure 1 with a bit more specificity, using agriculture as the example college. This typical university is fortunate that it is not so complex to need chancellors and vice-chancellors. Also, to simplify further, this organization chart, unlike figure 1, does not show the morass of linkages between and among associate deans and vice-presidents, nor does it show any assistant deans within the example college of agriculture.

Notice that the repugnant title of director has been eliminated, but several severe problems still remain (fig. 2). First of all, look at the roster of

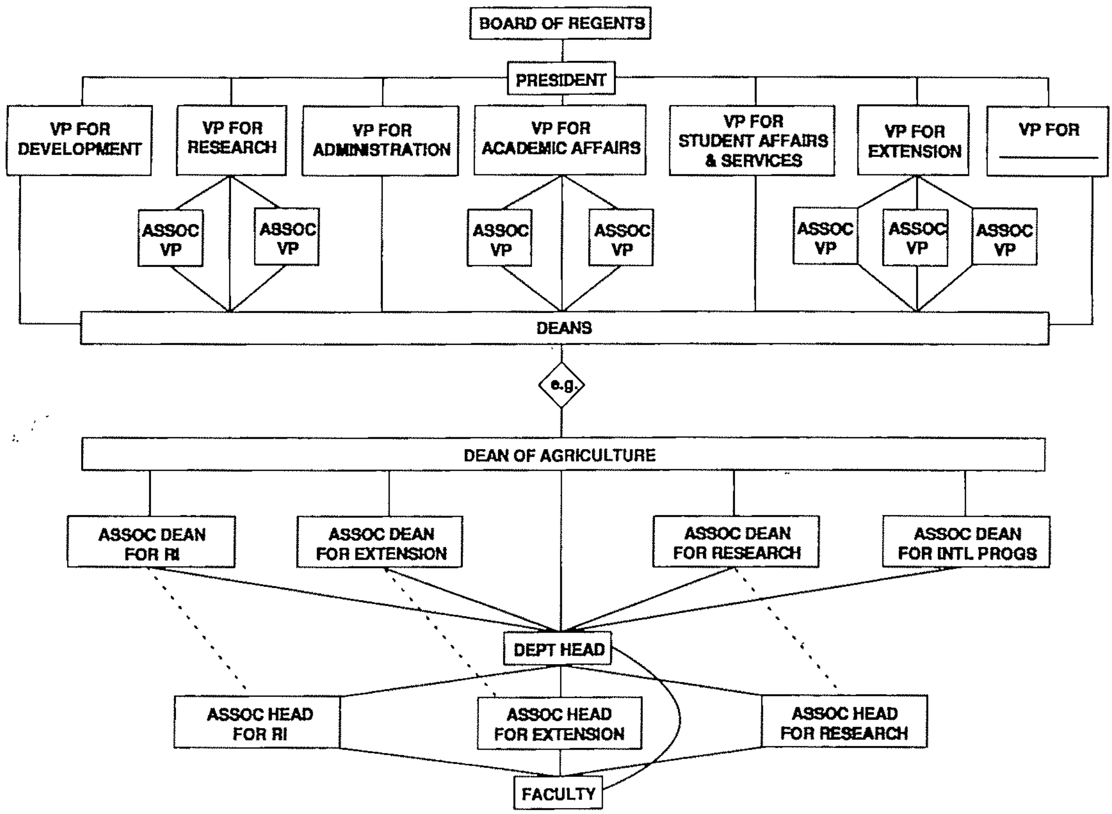


Figure 2. A more specific, simplified university organization chart

vice-presidents. Remember that often this is the cast of characters that forms the president's cabinet and sets the larger direction and resource allocation decisions for the university. The most notable problem here is that typically fewer than one-half (often many fewer) have programmatic responsibility central to the academic mission of the university. In fact, it is sometimes the case that only one vice-president has main line academic responsibility, the academic VP or provost. The implication of such a situation for core academic programs within the university is not promising. I might add here that one would expect the VP for research and the VP for extension to be strong advocates for the primacy of academics within the greater university, but unfortunately this is not always the case. Often the VP for research, no matter how well intended and oriented he or she might be, over time becomes principally a tax collector for the university, often working at odds with faculty who are attempting to garner resources to do their jobs and be creative. It never ceases to amaze me, the number of such individuals who measure their success and the success of the university in terms of total grant and contract dollars, not to mention indirect cost dollars. generated, as though that were some measure of output or productivity. (I will return to some of the pitfalls of this mad dash to individual and institutional stardom through grantsmanship later in the paper.) And, equally unfortunate is the fact that some VPs for extension (or in some cases, directors of extension) are far too preoccupied with service per se and not necessarily extended education or teaching.[1]

A second and crucial problem with the administrative structure depicted in figure 2, as Johnson (1987b) has pointed out, is its *disintegrative* nature. For purposes of completeness, the separation of resident instruction, research, and extension is shown at the vice-presidential level, at the college level, and at the departmental level. Obviously, this functional separation does not occur at every level at every land

[1] By the way, the blank VP position is for you, the reader, to fill in your favorite. In doing so, might I suggest you choose one for which "blank" best describes your perception of the duties, performance, and need for the position. Every university will have at least one such VP position.

grant university, but I dare say it is characteristic of most. Please note that on my version of the typical organization chart, despite the disintegrative functional organization at the department and dean levels, there is a solid connecting line between the faculty and the department head and between the department head and the dean. When these lines do not exist (and sometimes they do not), the problem of disintegration is even further exacerbated. The structuring of our administration along functional lines is not conducive to a concept of oneness of purpose and of the faculty. It is unfortunate indeed that our land grant universities are burdened with an administrative structure that falsely separates that which should be inseparable, namely, resident teaching, nonresident teaching or extension, and research and creative activity. We, in colleges of agriculture, are the most guilty of all in this regard. It separates and divides us in a way that is particularly debilitating and counterproductive in our efforts to achieve equal standing for all forms of instructional/educational efforts along side and in concert with research. Such a structure contributes to what Farrell and colleagues have called "a culture of separatism" between extension and the rest of the university. I think the same might be said for resident instruction.

The very idea that research should be thought of separately from teaching is unfortunate. It is foreign to the very conception of a university. As Watts and I have argued elsewhere, it is foreign even in common usage of the term university as codified in most dictionary definitions (Beattie and Watts). In terms of agricultural economics specifically, Warren Johnston reminded us as recently as last year that, indeed, the common glue of our profession is applied research. It is not some (functional or) subdisciplinary interest groupings that constitutes the core of our profession, rather our common interests in the conduct and application of research in either a "disciplinary, subject-matter or problem-solving" context that is our central core (p. 1119) (my addition in parentheses). I submit that the notion of separation of research from teaching is especially repugnant to the majority elements of the university outside of colleges of agriculture. If we within colleges of agriculture and those at top levels of the university truly believe that all three functions are important, then we would, curiously enough, best serve our cause by making less, not more, of a distinction between the functions. Would it not be nice just once to hear a university president say, "Teaching, including extension, is so important and so intertwined with active involvement in research that I herewith announce elimination of the positions of vice-president for research, resident instruction and extension and am assigning those responsibilities to the provost/academic vice-president." Would it not be nice to hear a dean of agriculture say, "The missions of resident instruction, outreach, and research are so important and crucial that I am forming a new position of vice-dean of agriculture, and am eliminating all the line associate dean and director positions." Rather, what we almost inevitably hear is exactly the opposite. Statements like, "Extension is so central to the mission of this university that I am creating a new vice-presidential level position to raise this function to its rightful position in the university." And what is the consequence? Almost always just the opposite of what is desired ultimately happens. The inseparable function becomes separate, loses standing in the minds of the majority of the university faculty, with the usual consequences.

If we learned nothing else from the great civil rights movement in this country, we learned that the concept of "separate and equal" is an oxymoron! If extension and/or resident teaching are somehow separate or separated (administratively, in annual merit evaluation, in promotion and tenure, in housing/space arrangements, or in purpose), then they will undoubtedly not be equal to each other or, most importantly, to research/creativity in status or reward. How many land grant universities either have, or are seriously talking about, separate merit evaluation processes and/or criteria, separate promotion and tenure processes and/or criteria, separate housing arrangements (buildings, floors, wings, or office suites), separate secretarial assignments, etc., for extension faculty or undergraduate teaching faculty? All such arrangements, however major or minor, contribute to "the culture of separatism" and divisiveness of mission and purpose of our land grant universities. Such policies and arrangements must be resisted continually.

Many top university officials are smitten these days with an especially bad idea that is being championed as a means to elevate teaching (including extension) to higher status within the university. The logic follows these lines. University productivity will be enhanced by recognizing the diverse interests and abilities of faculty, i.e., exploit comparative advantage through specialization. And we are to accomplish this by recognizing the distinct and equal

"scholarship of discovery, of integration, of application, and of teaching" (Boyer). This separate-but-equal philosophy is to be formally recognized through "differentiated staffing" with "different tracks" for merit evaluation and for promotion and tenure based on appointment, assignment, funding or expectation in resident instruction, nonresident instruction, and/or research. The idea sounds innocent enough. The problem, to be sure, is not with recognizing and capitalizing on the benefits of some degree of specialization. But, formalized "different tracks" for promotion, tenure, and merit evaluation is another matter. Such ideas will most certainly not foster a sense of oneness of purpose, mission, and standing among the university faculty. Such notions tend to separate, and with separation, inequality of status and reward will undoubtedly prevail (in the long run if not sooner). Rather than separate tracks, what is needed, in my mind, is a modest fine-tuning and broadening of the existing single track.

There is yet another reason a functionally separate administrative structure is debilitating to colleges of agriculture. This is a bit of an aside, but nevertheless it is a pragmatic and important problem. Without question (I think) our deans of agriculture carry a much greater administrative responsibility than their counterparts in other colleges. Deans of agriculture have external responsibilities involving extension, branch station management, public relations for the college and university, and budget garnering, second only to the president. Consequently, we often find ourselves with no one tending the store when crucial resource allocation and policy decisions are being made on campus. An associate dean, or deans as the case may be, filling in for the dean, is (are) often outmaneuvered, outflanked and certainly outranked when the provost calls a meeting of the deans. (The University of Arizona has gone a long way toward fixing this problem by naming a strong and effective vice-dean from among the usual cadre of associate deans.) It is crucial in the ongoing resource allocation process that our colleges of agriculture be represented by a strong functionally integrated administrator with appropriate standing among the competitors. The typical college of agriculture administrative structure is often not conducive to that outcome.

Again, the fundamental integrality of the discovery and dissemination of knowledge, i.e., research and teaching (resident and nonresident), is so imbedded in the consciousness of the academe, and rightfully so, that it is imperative that we reorganize ourselves administratively to correct this fundamental structural inconsistency. To this end I offer you my ideal land grant university organization chart (fig. 3). Recall, this is to be followed with an almost-ideal, but hopefully politically acceptable, alternative. So do not panic!

In my idealized view of things, I include (above the top dashed line) those the university presumably serves—our students of all varieties—labelled "external" public. The limiting of our external public exclusively to those carrying the title of student is not an oversight, it is purposeful. I wish to emphasize the primacy, in fact, exclusivity, of the educational mission (see also Beattie and Watts). In my world, all that is legitimate that the university does must be captured one way or another under some output category where the recipient of the service is in a learning mode. I accept no other purpose for a university and I allege it is the only purpose for which we have a comparative advantage. And, in this day of shrinking real budgets it is more than we can do well. While those an organization serves are not normally part of the formal organization chart of the institution, it is useful here to provide context.

Before leaving the matter of our "external public," a term (in addition to director) that we in colleges of agriculture and the extension service should purge from our vocabulary is that of "clientele."[2] It should be dropped in favor of nonresident students. The words client and clientele conjure up bad, or at least inappropriate, vibrations for many academicians. Immediately, I think of a doctor writing prescriptions, or an attorney giving an opinion, an accountant filling out my tax forms yet another year, the plumber unplugging the drain one more time, or "Mr. Goodwrench" doing the annual tune-up on the family car. The professional-client relationship is one characterized as repetitive, service oriented, and, most important, does not involve an intended teaching/learning experience. Consider the dictionary definition of client: "**1:** one that is under the protection of another: DEPENDENT **2a:** a person who engages the professional advice or services of another ⟨a lawyer's ~ *s*⟩ **b:** CUSTOMER ⟨hotel ~ *s*⟩ **c:** a person served by or utilizing the services of a social agency ⟨a welfare ~⟩ . . ." (A Merriam-

[2] The author is indebted to Myles Watts for pointing out the critical and subtle difference and importance of distinguishing between students and clientele as well as the repugnant nature of the title of director in a university setting (discussed earlier).

Webster, p. 248). Notice the subservient role and dependency status of the client that is involved in the professional-client relationship. (My dependency on people who can fix mechanical things is total, repetitive, and hopeless. There are certain things in life I never intend to learn how to do—like how to run a VCR, let alone fix it. Thank goodness for people who can. They are important and highly valued members of society as far as I am concerned.)

But the so-called "clientele" of the university, in particular those whom extension serves (or at least ought to serve) are fundamentally different. Our comparative advantage, and I submit our only legitimate purpose, is to teach those who come to us how to do it themselves; we must engage them in learning. If there is no learning involved, then surely there is a better way, a less socially expensive way than \$40 to \$100 K professors to provide such services, including the dissemination of research-based information. Again, appealing to my 1989 Merriam-Webster: a student, in contrast to a client, is a "**1:** SCHOLAR, LEARNER . . . **2:** one who studies: an attentive and systematic observer . . ." (p. 1170). We can dream, I suppose! But do notice that the focus is on learning, and I submit that this distinction is fundamental and important. Among other things, it has important pragmatic implications. Faculty are much less likely to become captured by their students than by their clientele, who are by their nature dependent, maybe even desperately so. Faculty and students do their work together; they are jointly engaged in a learning situation and opportunity. I submit the student-professor relationship is different, special, and socially valuable; it should never be confused with the equally important relationship between other professionals and their clients. The responsibility to engage others in a learning situation is a special opportunity, and we must never forget that this responsibility is all of what we are about. Whether engaged in classroom instruction, nonresident (extension) instruction, or research (some of which is to teach ourselves and our peers), the exclusive purpose (single mission, if you will) is teaching/learning (Beattie and Watts, Watts).

Between the two dashed lines in figure 3 are the "internal facilitators." The direction of facilitation should be from the bottom up; some administrators and some faculty have been known on occasion to forget that fundamental point. Faculty fall into the category of facilitator only as related to student learning and development. Department chairs, deans, and the academic vice-president, if they do their jobs well, focus the vast majority of their attention on serving the needs, i.e., facilitate the agenda of the faculty and student education. This facilitation involves mainly coaching, cheerleading, clearing the path of debris, and serving as referee. Coaching, cheerleading (including making the case to upper-level administrators for protection or augmentation of his/her unit's budget), and clearing the path of debris are primary and the most beneficial roles for the facilitative-minded administrator. These are valued characteristics in successful administrators. Every game is governed by rules of conduct, and the academic game is no exception. To be sure, a fair bit of administrator effort must be devoted to refereeing. Faculty and students are, after all, real people; and real people will all at one time or another, in the pursuit of self-interest, take some liberty with the rules of the game. (See Beattie for more on the facilitative role of administration).

The most important feature of the "internal facilitator" block of figure 3 for our purpose is to note that all assistant or associate heads, deans and VPs are cast in a staff role rather than a line position. The disintegration of figure 2 has been officially eliminated. To be sure, the jobs of department head, dean, and provost in most, if not all, of our land grant universities are more than one person can say grace over. These people need help. They need advice and counsel and considerable staff support on a daily basis. While these offices should be lean and mean, it would be naive to think in this day and age of accountability and litigation that most of the assistant and associate positions can be eliminated (although I am confident, as are many of you, that a number could be eliminated and the productivity of the university enhanced!). The key feature is a minimum number of levels and oneness of function—resident instruction, nonresident instruction, and research/creativity, it is all the same ball of wax.

Finally, below the bottom dashed line of figure 3, we have our "external facilitators" in contrast to "external publics" at the top of the chart. I trust most of you have no difficulty with the notion that the job of president (and below) is mainly external to the university. Theirs' is the important role of public relations and budget garnering that without question is crucial to the short- and long-term health of the institution and unquestionably a full-time job these days.

Since even I, with my great insight and power of persuasion, will not likely convince most people to view university administrative struc-

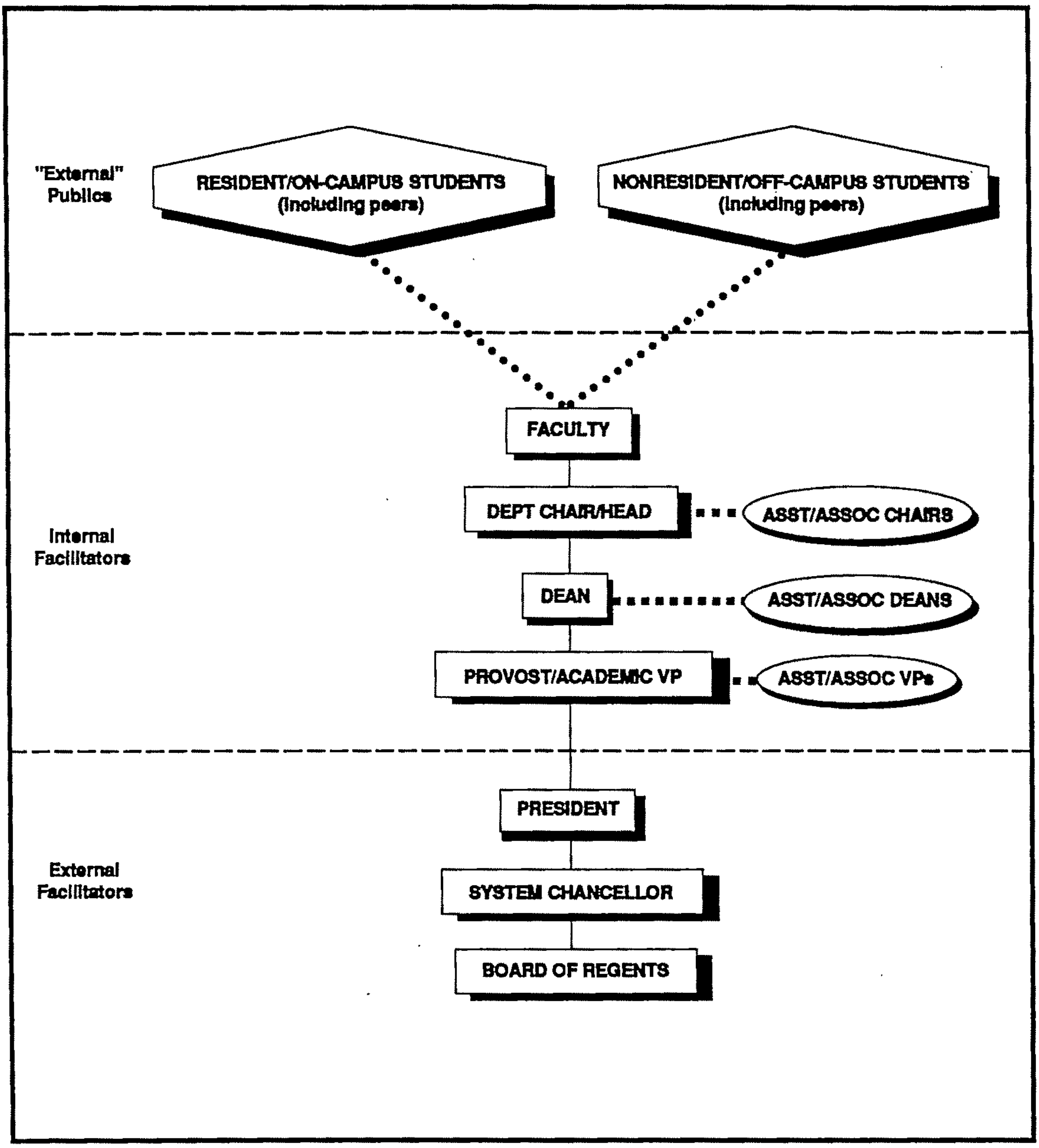


Figure 3. An ideal university organization chart

tures right-side-up, I offer figure 4 as an almost-ideal structure in the hope that it is something toward which we might strive. By way of summary, the key features are the following:

1. The president position is recognized for what it is—mostly external, with little responsibility for management of the academic enterprise.

2. The provost/AVP is the chief academic and managerial officer of the university and its only vice-president. All other VPs carry with their titles the modifier, associate or assistant, and are answerable to the provost. (In larger complex institutions this cast of characters will be admittedly large).

3. At the college level, the dean has responsibility and administrative authority for all academic functions germane to that college including resident and nonresident instruction and research/creative activity. In the case of the col-

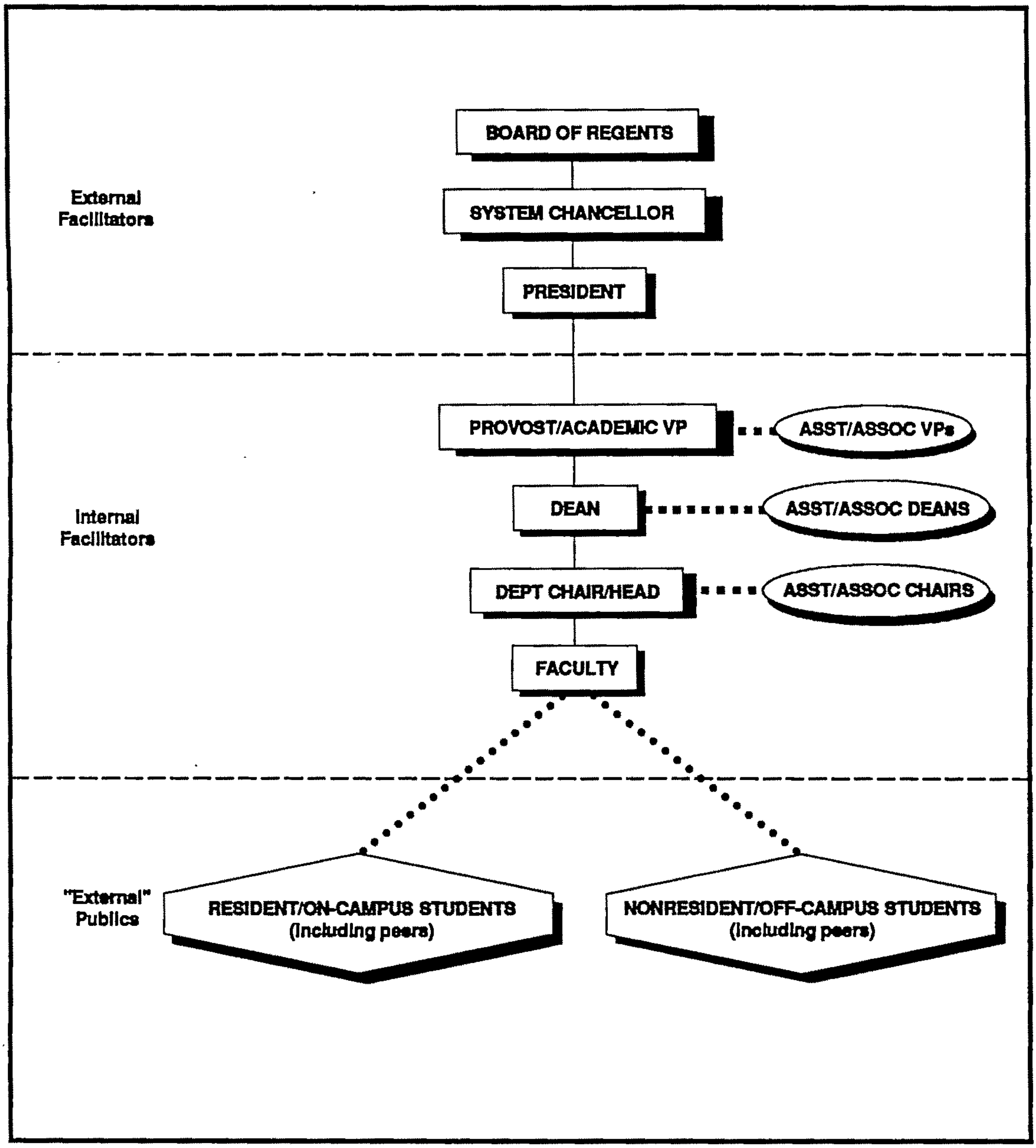


Figure 4. An almost-ideal university organization chart

lege of agriculture, it may be necessary to add a single vice-dean as a line position given the external demands on the dean's time.

4. Ditto 3 for the department chair level.

5. Faculty must always remember that they too are facilitators, that their exclusive function is education and in a university that includes both the discovery of knowledge and the transfer of knowledge to students in a manner conducive to learning.

6. Only persons above or below on the vertical chain report to, answer to, ask of, demand of, or whatever of others.

7. All titles of director are eliminated.

8. All persons served should be thought of, and where feasible referred to, as students, and university interaction with same should be in an educational/teaching context.

I admit and recognize that these views are extreme and there is much gray area. Neverthe-

less, I believe that principles are important in guiding our actions and day-to-day work. I submit that if the principles imbedded in figure 4—limiting the university's role to that of teaching, minimizing administrative levels, and eliminating all possible opportunities for functional disintegration—were front and center in all our minds, it would help immeasurably in our revitalization efforts. In particular, it would give those of us with interests in applied research and extension an opportunity to win over the mainstream of academia by eliminating terminology and ideas that are repugnant to them. I turn now to a second area of crucial importance in providing direction in the university, the matter of faculty evaluation and promotion and tenure.

Faculty Evaluation

A former colleague of mine at Montana State, Richard Stroup, had a favorite expression, which I hereby proclaim as Stroup's Law (see also Gwartney and Stroup, pp. 8–9). Stroup's Law is the most fundamental of economic laws in that virtually all other economic laws and principles follow from it (except the law of diminishing returns which really is not an economic law anyway). Stroup could almost daily be heard to say, "Well I'll be, *incentives matter*!" It is rather amazing how much of our lives we are constantly bombarded with policies, great ideas, and all manner of wondrous things for which the proponents are flabbergasted to discover consequences entirely different than intended or expected. We economists know, if we know anything, that changes in policies and rules and regulations inevitably involve changes in incentives and that human behavior will be altered accordingly. It is this propensity of we economists to be looking for, and gleefully pointing out, these unintended consequences that endears us to our colleagues in and outside the university and to politicians and their constituencies.

As good as we are at this, and even with our constant vigilance to the notion that a change in the incentives will without doubt bring about predictable behavioral response, it is interesting, I think, that so many of us are so often surprised to find that the model also applies to the behavior of professors. Sure enough we too respond to incentives, self-interest, and all those things we economists attribute to real people. In our case, response occurs perhaps even to some of the annual merit evaluation and promotion and tenure criteria nonsense that we impose on ourselves and our colleagues. To conserve time and space (not to mention lost energy and creativity on the part of the author) I dispense with "the way it is" and "the ideal" and move directly to "an almost-ideal faculty evaluation/reporting instrument for land grant universities." Actually, no great harm is done here in that most of what is ideal with respect to faculty evaluation is, I expect, potentially doable in most land grant university environments. And most of you are as familiar as I am with many of the wondrous items that presently appear on faculty evaluation/reporting forms—things like involvement in interdisciplinary efforts, creative and imaginative teaching methods employed, grant and contract dollars generated, research activities (as opposed to output), extension program planning activity, and the list continues *ad nauseam*.

The main problem with our faculty evaluation (incentive) structures is the propensity to confuse input with output, means with ends. It happens over and over again and at every university with which I am familiar. Productivity, at least to an economist, should have something to do with output relative to input. A measure to which many of us could relate might be "quality-adjusted output per unit of input,"[3] where output is expressed (thought of) in terms of final demands of the university. Initially, let me presume that there are some quantifiable final demands of the university for teaching (both resident and nonresident students) and for research as it might be delivered through some teaching medium. The problem with university evaluation/incentive processes is that invariably we want to count means and process as output when it is in fact input, so we end up seriously understating the denominator and overstating the numerator in productivity calculations. Faculty, being reasonably bright and sometimes rational economic men and women, respond not surprisingly.

In terms of "the way it ought to be," I give you my "almost-ideal faculty evaluation/reporting instrument" (table 1). Notice two key features of table 1: service has been degraded to minimal status, i.e., a necessary evil that must be done well yet nevertheless minimized, and extension has disappeared. Or did extension disappear? Actually it did not, rather it has been upgraded, renamed, and fully subsumed within the single and most important function of the university, namely teaching, nonresident teach-

[3] The author owes this terminology to Jeff LaFrance.

ing to be precise. (I believe this is consistent with Henderson's view that education [teaching] is the basic mission of extension.)

Now you may say, what is the big deal—just semantics or, worse yet, extension has now been downgraded even further to the status of undergraduate instruction; we all know the university could give a hang about undergraduate instruction and those who do it well. Just look at what universities do, not what they say, not their rhetoric. On that point I must confess to some uneasiness. Whether or not the status of undergraduate instruction will rise at land grant universities is yet to be seen. Nevertheless, I believe a strategy of subsuming extension education within the umbrella of teaching/instruction is a good one, particularly if the goal is to gain recognition and raise the status of extension faculty in the minds of the greater university faculty, who for the most part do not have the foggiest idea what extension is all about and who are, to say the least, suspicious.

I submit that language makes a difference; it is not just a matter of semantics. I have only anecdotal evidence from serving on "umpteen" different college and university committees. But my interaction with faculty and administrators from across several campuses impresses upon me how much of a "black box" the extension service and the agricultural experiment station is to those outside the college of agriculture, including upper-level administrators with agriculturally related backgrounds who have spent their entire careers in and around land grant universities. Faculty and administrators outside the college of agriculture have not the faintest idea about extension and the agricultural experiment station, could care less, and are suspicious that faculty associated therewith are engaged in fluff, are inferior academics, and are overfunded and underemployed.

Is there some truth to what they say? If there is not, is there reason to blame them or point fingers at them for not knowing what it is we do, or to condemn them for abandoning or not understanding or appreciating the tripartite mission of the land grant university? I think not. Rather we would serve our self-interest and the cause of resident and nonresident teaching and of applied research by changing our, not their, mind-set. We must infiltrate the game following their rules, adopting their academic jargon, their administrative structure, their passion for academic excellence, their insistence of arms-length relationship with "clientele." I believe a strategy of infiltration and winning from the inside is surely wiser than emphasizing our differences and our enlightened and presumably superior sense of the land grant mission. Colleges of agriculture are but a small cog in the land grant university wheel. That wheel is not all bad and is capable of understanding where we are coming from if we will but give it a chance, by making ourselves more like the wheel rather than fighting a losing battle of hoping the entire wheel will mold itself in the image of a shrinking cog. Friends, right or wrong, remolding the university in the image of colleges of agriculture "ain't a gonna happen!" We have to buy in, we must adopt their language, their mind-set and their ideals. Once we have done that, then I believe we will be pleasantly surprised how many within the rest of the university share our interest in applied research and in teaching willing learners wherever they might be.

One more item by way of setup before we take up the details of faculty evaluation implicit in table 1. That is, Beattie's "First Rule of Faculty Evaluation: Beware the Bean Counters!" Anyone who desires to reduce, or who thinks faculty evaluation can be reduced, to a numerical process with subcategory scores ultimately giving rise to a weighted-average grand total score is NUTS. Evaluation is subjective and that is the way it is—PERIOD. Ultimately, some will be judged more productive than others, some will get higher raises than others, some will make promotion and some will not, some will gain tenure and some will not. It is inherently a process of shooting at a moving target with constantly changing judges with their own principles, ideas, and criteria (Johnson 1987a). It is not great, but it is workable and, in my view, better than overly structured, overly detailed, overly quantified, naïve alternatives.

I believe a simplified faculty reporting instrument limited to just the items on table 1 serves the purpose of (*a*) heightening the status of teaching including nonresident teaching, (*b*) keeping the focus on output rather than input and/or process, and (*c*) relegating service to internal busywork having to do with running the academic enterprise, not to be confused with the output of the enterprise. I believe this is the way that the academe (outside of colleges of agriculture) has viewed the role of university professors for eons.

With regard to teaching/advising (table 1) only three things are important: (*a*) the amount of teaching I do, (*b*) the quality of that teaching as subjectively perceived by my partners in the learning process, viz., students, and (*c*) the

Table 1. An Almost-Ideal Faculty Evaluation/Reporting Instrument for Land Grant Universities

I. Teaching & Advising
   A. Resident (undergraduate & graduate)
   B. Nonresident (formal & informal)
   C. Awards & recognition
II. Publications & Other Evidence of Scholarly Output/Accomplishment
   A. Publications
   B. Other research output
   C. Awards & recognition
III. Service (Chores)
   A. To professional societies
   B. To department, college, & university
   C. Grantsmanship (NPEO)

quality and content of that teaching as subjectively perceived by my disciplinary peers. This is true whether my teaching is of the classroom or one-on-one variety, whether my students are resident or nonresident, or whether my instruction is formal or informal. And, it makes absolutely no difference what teaching methods I use, old yellowed lecture notes or the latest technological gadgetry! Evidence of one's teaching quantity, i.e., (*a*) above, and quality, i.e., (*b*) and (*c*) above, must be offered for annual merit evaluation and for promotion and tenure. A judgment must then be rendered by peers (including the appropriate disciplinary administrator) *vis-à-vis* one's colleagues and some notion of minimally acceptable performance for promotion and tenure. The process, especially that of evaluating quality-adjusted teaching and research output, can not be reduced to a mindless mechanical/clerical process. There are times when the continued pursuit of quantification is not the way to go—faculty evaluation is one of those instances.

Returning to table 1, notice that under "Publications and Other Evidence of Scholarly Output/Accomplishment" publications are not subcategorized into peer-reviewed (important) and lay- or student-oriented (unimportant). I expect I may be the last professor of my cohort (or younger) that still does not have publications classified on his/her curriculum vitae by various categories. I refuse to do it. (The fact that I have never had to stand for a real P&T review probably has something to do with it!) The point is that subcategorization of publications is just another form of unnecessary disintegration in land grant universities, and it should be discouraged, not institutionalized or encouraged. Some of my best papers appear in peer-reviewed journals, so do some of my worst. Some of my more valuable scholarship appears in lay-oriented publications. To reduce the concept of scholarly contribution to the mere counting of refereed journal articles under some pecking-order of journals is to oversimplify the notion of research productivity, i.e., "quality-adjusted output per unit input," to say the least. Such subcategorizations are especially silly on annual merit review reporting forms. If someone writes so many papers in a given year that I cannot sort out what is there, then the appropriate conclusion is that individual has written too much for any of it to be of much quality! It is not out of the range of possibility that an annual faculty productivity report with one refereed journal article and two lay-oriented pieces could represent greater scholarly output and social value, than a full page of refereed paper titles.

Service, the last item on table 1, is problematic. Service in a university and a professional association such as the AAEA is a cost of doing business rather than an educational output. But benefits of well-done service accrue to our colleagues, and those who do these chores well deserve some reward lest we all decide the best strategy is to free ride. The main point to remember is that within the university, intramural service of a colleague can be valuable in terms of facilitating the agenda of one's peers, and is therefore meritorious. But for the university as a whole, intramural service is not a final-demand output.

The problem of what to do about grantsmanship is more difficult. You will notice on my list that grantsmanship is listed under service (chores) and that it is followed by the initials NPEO or "net positive externalities only." Grantsmanship is much like intramural service; if our peers are good at it, then it is entirely possible that the effective resource base of a department, above and beyond the resources needed to complete the contracted research, is enhanced. From this and only this viewpoint, grantsmanship should be considered in evaluating the performance of individual faculty. The part of the grant that is expended in the conduct of the grant's intended purpose is not an output, but rather an input. The output of that input is what should be counted—the research and/or educational literature produced, the graduate or undergraduate students trained, or the workshops and conferences conducted—but not the grant dollars generated. We must not confuse input with output when attempting to evaluate productivity; inputs go in the divisor and outputs (including net positive externalities) in the numerator.

As alluded to earlier, there is not one vice-president for research in the world who understands the importance of this fundamental accounting distinction. The opportunity for perverse outcomes as our land grant universities become increasingly dependent on grant and contract funds for their day-to-day operation is not pleasant to contemplate; perhaps we should ask one of our colleagues from Stanford about the risks involved in this ratrace to university stardom through grantsmanship. It is an area of faculty evaluation and university management that needs some serious attention and thoughtful consideration, especially in these times of budget stress. It is such times when those of us in administration might be tempted to throw caution to the wind and embrace anything and anyone who has money that might generate some desperately needed indirect cost recovery to replace our ever-shrinking hard money operations support. Remember "Stroup's Law"; incentives do matter, even to level-headed, highly principled, and infallible administrators!

As with university administrative structure, it has been my experience that our colleges of agriculture are among the worst offenders in coming up with all kinds of nonsense when it comes to faculty evaluation and promotion and tenure. I am amazed how often college of agriculture department heads and faculty express the belief that evaluation and P&T criteria should be considerably different for faculty with different funded-appointments, like if God had meant for philosophers to do research then She would have created a philosophical experiment station. Or, as is more often the case, if Professor *X* in animal science has no experiment station appointment, then it is appropriate (perhaps even desirable) that he be judged solely on the basis of his teaching for merit and promotion and tenure. And certainly in extension we are far too prone to confuse or substitute process for output in evaluation matters. Again, such behavior on our part confuses and puzzles our peers in the rest of the university. It hinders our efforts to gain respect and higher status for nonresident teaching and applied research.

Conclusion

There seems little doubt that our land grant universities, their colleges of agriculture and extension services, and their departments of agricultural economics are "under the gun" (or at least believe they are). Allegations of lost focus and mission, of misplaced emphasis, of self-serving professors rather than professors tending to the needs of their students and of society, and of sustainability are common themes of addresses, papers, strategic planning efforts, and study commissions. These topics and efforts seemingly occupy a disproportionate share of the time and energy of top-level administrators and others in our land grant universities and their colleges of agriculture. It may even be possible that the amount of introspection is out of control relative to any hope of insight or benefits from such introspection. Despite that distinct possibility, this paper attempted to provide some specific suggestions for fine-tuning within the land grant system (and colleges of agriculture in particular), to focus attention on the one function/mission for which universities have a comparative advantage, and to get on with the task of heightening the status of, and fully integrating, resident and nonresident teaching within the university administrative and reward structures. Suggested institutional reforms were offered in the belief that winning the internal war (getting our house in order) is an essential prerequisite to winning the external war for the hearts, minds, and pocketbooks of those we serve and who sustain us.

To that end, several specific recommendations were made in the paper:

- Land grant university administrative structures, and especially the administrative structures of colleges of agriculture, should become more integrated with respect to teaching (resident and nonresident/extension) and research. In the process, the number of levels of line administration can and should be reduced.
- We should purge our vocabulary of the term clientele in favor of student, especially in colleges of agriculture and the extension service. Students are fundamentally different from clientele, and the university's exclusive business (single mission) involves teaching students in their many varieties. (Also, I take as a given that, for all individuals aspiring to the title of professor, the expectation of knowledge discovery [research] is part and parcel of the teaching function, and I might add that is true irrespective of the professor's budget/appointment split.) And, while we are at it, it would not hurt to use the term nonresident instruction rather than extension at every opportunity.
- We should purge the term director from our administrative vocabulary. The concept of director has no place in a university setting. There may be a place for directors at the head of an orchestra, or a manufacturing division of IBM, or in state or federal government. But in a university, definitely not!

• Faculty incentive/reward structures must be coherent, consistent, productivity based, and as simple as possible. The agreed upon measure of productivity should be quality-adjusted output per unit of input. All items that can not be articulated in terms of the legitimate final-demand outputs of a university should be stricken from (or greatly de-emphasized in) all merit evaluation and promotion and tenure criteria statements and documentation.

In violation of an important rule of good writing, I offer two additional thoughts not heretofore discussed in the paper.

• Active participation in meeting the undergraduate teaching responsibility of the university should be an expectation for every tenure-track faculty member except for those whose teaching responsibilities are off campus (extension) and except for those program areas where there is no or only an inconsequential undergraduate program. In the case of agricultural economics, there are few teaching/research funded faculty so valuable in research or graduate education that they should be totally excused from teaching an undergraduate class at least every other year. Undergraduates deserve, and the taxpayers pay handsomely for, the privilege of exposure and interaction with the greatest minds our profession can provide. Teaching undergraduates is not a second-class occupation; in fact, it is a kick in small dosages (and for agricultural economists the dosage typically is not that onerous).

• Finally, academic agricultural economics is surely an undergraduate-program-dependent profession. There is not a good, reliable supply of grant and contract dollars for basic or applied research to support an exclusive research/graduate program effort for anything like the entire academic agricultural economics enterprise as exists today. As a pragmatic matter, undergraduate interest in agricultural economics has been, and will continue to be, dominated by undergraduates with interests (at least initially) in agribusiness. Our programs and faculty would be wise to accommodate (in some way) to this reality.[4]

To be sure there are plenty of reasons to be pessimistic about the future of land grant universities, their colleges of agriculture, and agricultural economics. We, the members of AAEA, have reason to be concerned about the health and welfare of all three, especially the latter. The future is uncertain, but if we remember always to emphasize quality and to get in harness in so far as possible with the mind-set of academia generally, then surely there is reason to believe that someone will "turn the light back on at the end of the tunnel." As my friend and colleague, Jeff LaFrance, often says after something good happens, "Life ain't always bad!"

It is perhaps a bit trite, but surely our future is mostly up to us. Dan Padberg advises us well: we must learn to give a better play from an unstable institutional stage rather than the sometimes mediocre play we became accustomed to giving from the all too familiar and stable stage of the past. As I look to the future, I can not help but be optimistic. I observe, in the generations of economists following mine, an enthusiasm, the theoretical and quantitative skills, the analytical rigor, and the imagination that would make any father or mother proud. I believe we are in for some "fine plays" and for several years to come.

[4] The author had originally hoped to discuss a few ideas explaining how we economic-purists could "have our cake and eat it too" with regard to agribusiness, ideas that would keep economics rather than business front and center and would at the same time permit us to turn out a competitive and valuable student product to society. But, given time and space constraints, I leave that for another time and place.

References

Beattie, B. R. "Ten Commandments for Agricultural Economics (and Perhaps Other) Administrators." *West. J. Agr. Econ.* 8(1983):209–14.

Beattie, B. R., and M. J. Watts. "The Proper Preeminent Role of Parent Disciplines and Learned Societies in Setting the Agenda at Land Grant Universities." *West. J. Agr. Econ.* 12(1987):95–103.

Bonnen, J. T. "A Century of Science in Agriculture: Lessons for Science Policy." *Amer. J. Agr. Econ.* 68(1986):1063–80.

Boyer, E. L. *Scholarship Reconsidered: Priorities of the Professoriate.* A Special Report: The Carnegie Foundation for the Advancement of Teaching. Lawrenceville NJ: Princeton University Press, 1990.

Bromley, D. W. "Re: Ed Schuh's 'Revitalizing Land Grant Universities.'" *CHOICES*, no. 1 (1986), pp. 39–40.

Enarson, H. L. "Revitalizing the Land-Grant Mission." Unnumbered monograph. Blacksburg: Virginia Polytechnic Institute & State University, 1989.

Farrell, K. R., et al. "Toward Enhancement of Applied Agricultural Economics Research and Extension Programs at the University of California." Unpublished report to the executive committee of the Giannini Foundation of Agricultural Economics, Sep. 1986.

Gwartney, J. D., and R. L. Stroup. *Microeconomics: Private and Public Choice*, 5th ed. New York: Harcourt Brace Jovanovich, 1990.

Henderson, D. R. "The Missing Blueprint for Progress, or What the Extension Futures Report Failed to Do." *Amer. J. Agr. Econ.* 70(1988):1127–32.

Hildreth, R. J. "Agricultural Economics: The Future of the Profession." J. W. Fanning Lecture, College of Agriculture, University of Georgia, presented 24 May 1991. (To be published by Dep. Agr. Econ., University of Georgia.)

Johnson, M. A. "Promotion, Tenure and the Extension/Research Interface." Dep. Agr. Econ. Staff Paper No. 88-3, Kansas State University, Sep. 1987a.

——. "Research-Extension Interaction." Paper presented at West. Agr. Econ. Council meeting, Monterey CA, 22 Jan. 1987b.

Johnston, W. E. "Structural Change and the Recognition of Diversity." *Amer. J. Agr. Econ.* 72(1990):1109–123.

McDowell, G. R. "Land-Grant Colleges of Agriculture: Renegotiating or Abandoning a Social Contract." *CHOICES*, no. 2 (1988), pp. 18–21.

A Merriam-Webster. *Webster's Ninth New Collegiate Dictionary*. Springfield MA: Merriam-Webster, 1989.

Padberg, D. "Saving the Land Grant System." Dep. Agr. Econ., Texas A&M University, 1989.

Schuh, G. E. "Revitalizing Land Grant Universities: It's Time to Regain Relevance." *CHOICES*, no. 1 (1986), pp. 6–10.

Smith, E. D. "Re: The Bromley-Schuh Interchange About Land Grant Universities." *CHOICES*, no. 1 (1986), p. 42.

Stigler, G. J. *The Intellectual and the Market Place and Other Essays*. New York: Macmillan (Free Press of Glencoe), 1963.

Watts, M. J. "The Function and Functioning of a Land Grant University." Dep. Agr. Econ. and Econ. Staff Pap. No. 91-11, Montana State University, 1991.

Open Economies: Implications for Global Agriculture

G. Edward Schuh

I am honored to be invited to give the Fellow's Address.

In my remarks today I want to address some of the issues associated with national economies becoming increasingly open. My paper is divided into three main parts: (*a*) some background on the rapidly changing international economy; (*b*) the elements of an analytical model for understanding the changes that are taking place in that economy; and (*c*) a discussion of some of the implications of increased openness for our profession. The thrust of my paper is toward the future, with the goal being to help us better understand the rapidly changing international economy.

Some Background

The international economy has experienced enormous changes in the period since the end of World War II. Many of these changes are familiar to us because they are so overt and apparent: (*a*) a growing dependence on international trade as trade has tended to grow at a faster pace than global GNP; (*b*) the emergence of a huge, well-integrated international capital market; (*c*) the shift in 1973 from the old Bretton Woods fixed exchange rate regime to what can best be described as a system of bloc-floating exchange rates;[1] and (*d*) the shift of the United States from being the world's largest exporter of capital to now being the world's largest importer and to being the world's largest debtor nation.

Somewhat more subtly, but no less important, is the changing basis for comparative advantage in the international economy. Investments in human capital are becoming increasingly important as the basis for comparative advantage as an ever-larger share of global increases in output come from that source. This trend is reinforced by the fact that an ever-larger share of the world's research and development (R&D) budget is now spent outside the United States. More specific issues include the continued increase in general education in the developing countries, which makes it easier for them to adopt the highly transferrable technology associated with the manufacturing sector, and the development in the tropical South of a growing capacity to produce the more location-specific biological technology associated with agriculture.

Foreign exchange markets have now come to be dominated by international financial flows. Moreover, the combination of the "flexible" exchange rate system and the well-integrated international capital market means that monetary policy now affects national economies in large part by inducing changes in the value of national currencies, thus forcing the burden of adjustment to changes in monetary and fiscal policy onto the tradeable sectors, of which agriculture is an important component in most countries (see Schuh 1976).

More recently, we have witnessed another significant set of developments, a growing movement toward economic integration. There were earlier attempts at such economic integration in the post-World War II period, some of which were successful. Probably the most successful example was the creation of the European Economic Community. However, there have been a number of attempts at such economic integration in Latin America in the post-World War II period, largely as an attempt to extend the import-substituting industrialization policies of the countries in that region after such policies had failed at the national level (see Corbo). These attempts include the Latin American Free Trade Association (LAFTA), the Andean Common Market, and the Central American Common Market. The Central American

---

Fellows address.

G. Edward Schuh is a professor and Dean, Humphrey Institute of Public Affairs, University of Minnesota.

The author is grateful for perceptive and helpful comments on an earlier version of this paper from D. Gale Johnson, Robert Kudrle, and Terry Roe.

[1] The system is bloc-floating because a fairly large number of currencies are still tied to one of the major currencies, which float relative to each other.

initiative was the only one of these initiatives which had any success, but it also eventually encountered difficulties. (For a discussion of these various initiatives in Latin America, see Schuh and Brandao.)

More recently there have been a number of significant efforts at economic integration. Perhaps the most notable of these is the Canada–United States Free Trade Agreement, which has a commitment to eliminate most barriers to trade across the border with the greatest amount of international trade in the world. Next in line for further integration is EC-92, which the Europeans describe as "the completion of the market." This initiative proposes to eliminate all barriers to trade and to resource mobility within the European Community by 1992.

Partly in response to the economic colossus that a fully integrated European Community would be, the United States has proposed the creation of a North American Free Trade Agreement, with Mexico to join Canada and the United States. If those negotiations should prove to be successful, it is most likely that other Latin American countries would join soon after because they would not want to let Mexico alone have preferential access to the large United States and Canadian markets. In fact, countries such as Chile and Venezuela have already indicated an interest in joining.

Many observers expect Japan eventually to create an economic community of its own in Southeast Asia, or possibly to join up with the United States. This has raised the possibility of a world of trading blocs, with many observers concerned that economic warfare would be the eventual result. Japan's creation of its own trading bloc is far from a foregone conclusion, however, because an amazing amount of economic integration has already taken place in the Pacific Basin and the world's economic center of gravity is rapidly shifting from the Atlantic to the Pacific. (For a perceptive and insightful discussion of the changing Pacific economy, see the papers in Commission on U.S.–Japan Relations for the Twenty-First Century.)

Interestingly enough, some examples of economic disintegration have taken place at the same time this integration has been taking place. For example, the countries of Eastern Europe have separated themselves from the Soviet Union, and the economic system (the Comecon) which tied these economies to each other and to the Soviet Union has been disbanded. Similarly, the Soviet Union itself seems to be in very real danger of dissolving into its various member republics.

It is these trends toward economic integration and disintegration that I want to focus on in the remainder of my paper. An important premise of my paper is that rather fundamental economic forces are behind an important part of the developments we are now witnessing, despite the obviously important political dimensions to them as well.

An Analytical Framework

Let me begin by returning to the statement I made in opening my paper. What the world has experienced over the period since the end of World War II is a gradual increase in the openness of national economies. International trade has grown faster than global GNP, and national economies have also become more thoroughly integrated by means of a rapidly growing international capital market. There is a tendency to describe these developments as a situation in which individual nation states are becoming increasingly dependent on trade and on the international capital market. However, a more useful, and in many respects a more insightful, way to view them is as an increase in the openness of national economies.

Open economies have some important distinctive features. Perhaps most important from the perspective of this paper is that as an economy becomes more open, it becomes increasingly beyond the reach of national economic policy. Perhaps U.S. experience with its agricultural policy is as good an example of this problem as one can cite. It is not the case that the federal government has not been doing anything about agriculture. To the contrary, U.S. Treasury costs of the programs have been quite high in recent years. Yet, despite these high costs, substantial problems continue in the agricultural sector. The problem is that forces from the international economy are simply swamping what the domestic policies can accommodate.

To be more specific, the emergence of the international capital market and the shift to flexible exchange rates means that even in economies as large as that of the United States, policy makers have lost control of both their interest rates and their exchange rates. The large rise in the value of the dollar in the first half of the 1980s, for example, was not just the result of the contradictory monetary and fiscal policies this country was pursuing but also the fact that Japan and the countries of Western Europe were pursuing policies that were just the opposite of ours.

Two things tend to happen as economies become more open. The first is that some part of economic policy making and implementation shift upward to the international level. When this happens, the policy becomes imbedded in the rules, codes, and disciplines of international institutions such as the GATT or in the form of the instruments of economic integration such as we are now experiencing. Second, while this shift upward of some part of economic policy making and implementation is taking place, another part of policy making and implementation shifts downward to the state and local levels. This shift in policy making and implementation in these opposing directions thus amounts to a bifurcation of economic policy. It is something that is driven by underlying economic forces, even though there are important political dimensions to it.

A casual examination of experience in the United States and other countries suggests that examples of such shifts are all about us. In the United States, economic policy making and implementation has shifted downward to the state and local level at a rapid pace at the same time that this country has signed a free trade agreement with Canada and shortly thereafter begun negotiations with Mexico to bring it into the agreement.

The shift downward in policy making and implementation has been prodigious in this country. State and local governments have been growing rapidly. The staffs and budgets of state government have expanded, as have salaries at that level. And we have what would have been unheard of as recently as a decade ago—our representatives in Congress resigning their positions to be a candidate for governor. They have figured out where the action is! At the same time, however, the signing of the Canada–United States Free Trade Agreement passed certain parts of economic policy making and implementation to the international level, where it is imbedded in the agreement, with disputes resolved by an international commission.

Clearly, however, this is not just a phenomenon of the United States. The Brazilian Constitution, which was promulgated just a few years ago, institutionalized a great deal of policy making and implementation at the state and local level that was once held at the national level. (Notice that Brazil is a large country.) In contrast, in the European Community, the main shift is upward, with more of the policy of an international kind. (Notice that Europe is made up of what are mostly small countries.)

Developments in Eastern Europe and in the Soviet Union also seem to be driven by the same sets of economic forces. What was once a hegemonic regime of economic policy has found itself under tremendous pressure to decentralize its policy making and implementation. The old economic unit was found to be no longer economically viable.

In trying to understand these trends, we find that a number of important questions arise. First, what was behind the original expansion of trade and of the international capital market which set these forces to work in the first place? The answer is that they have been driven by very significant technological breakthroughs. Among these are the significant breakthroughs in the transportation sector, both in terms of air and sea transportation, and the decline in the price of energy. The price of oil in real terms is now at as low a level as it has been since 1950. The second is a similar significant breakthrough in the communication sector, illustrated perhaps most importantly by the satellite communication systems. By lowering the real cost of transport and communication services, these two developments have enormously expanded the scope of markets.

Finally, there is the computer revolution. This development has contributed to the breakthrough in the communication sector. It has also made it possible to rapidly process large amounts of data and thus to make global trading and commerce a reality on a scale never possible in the past. In today's world, one can conduct a capital market transaction almost any place in the world at almost any time of the day.

A second issue is the differentiation of the policies that shift to the international level from those that shift down to the state and local level. In general, the policies that shift up to the international level will be those that focus on product markets. Similarly, those that shift downward will be those that focus on resource problems and/or that comprise incomes or welfare policy. These two shifts can both bring net benefits, and that is probably why they are taking place. As product market barriers are removed at the national level and shifted upward to the international level, trade liberalization takes place. In fact, I suspect that over the next ten years we are likely to see far more liberalization of trade by means of formal attempts at economic integration than by means of the negotiations of the GATT.

As policy shifts downward, on the other hand, it tends to become more differentiated toward the local resource base and toward incomes policy. This can make policy more efficient in at-

taining its goals because it will be more closely adapted to local conditions. At the same time, however, the shift downward in policy making and implementation can lead to serious equity problems as more well-endowed regions can do more for their citizens than the less well-endowed. Such geographic differences in the availability of public goods can give rise to labor migration in search of desirable mixes of such goods.

Another important issue is just how far the bifurcation process is likely to go. At the one extreme, one can imagine a completely integrated international economy, with only one set of "rules" and regulations for everybody. This would be the end of the nation state as we have known it and would probably argue for a global political organization for rule-making purposes. At the other extreme, we could imagine the reemergence of something approximating the old city state, with each "city" made up of a major metropolitan area and its surrounding hinterlands. From that perspective we can imagine the United States ultimately breaking up in the same way as the Soviet Empire is breaking up, with "states" emerging around our major metropolitan areas.

It is not likely that either of these extremes will emerge, although I believe it fair to say that we are likely to see, even in the next ten to twenty years, enormous realignments in political and economic configurations on the international scene. We are probably only at the beginning of what can be expected to be a very substantial process.

Fortunately, some pieces of analytical apparatus can help us understand the kind of world we can expect to emerge in the future. The first is the insights offered by the theory of optimal currency areas. This body of theory might have a great deal to offer in defining the national "countries" of the future. As the members of the European Community are about to learn, once one establishes a unified currency area, an underlying political process is needed to manage it.

The theory of optimal currency areas, as articulated by Mundell, argues that the domain of the optimal area is determined in large part by two conflicting economic forces. On the one side, the optimal currency area is defined in terms of a region, with the region defined as a geographic area in which factor mobility is greater within than is factor mobility between the region and the rest of the world.

Factor mobility is, of course, a relative concept. What usually imposes limits on it in the real world are national political boundaries. In fact, in the real world, currencies are mainly expressions of national sovereignty. However, in today's world, national sovereignty or ethnic identity are increasingly less important as barriers to resource mobility. This has been increasingly true in the case of capital, but even the barriers to the migration of labor are becoming increasingly more difficult to enforce, as evidenced by the migratory flows from Mexico and Latin America to the United States and by the growing concerns about potential migrations from Eastern and Central European countries to those of Western Europe.

Let us therefore suppose, for the purposes of analysis, that all national boundaries are erased and we are free to establish currency areas according to some other criteria. One possible, and widely accepted, method would be to impose internal economic stability as the criterion. That is, the criterion that the region (or country) be defined as one in which the economy can be managed so as to have no inflation or unemployment. Mundell notes that, the greater is the number of separate currency areas in the world, the more successfully will these goals be attained.

The difficulty with this outcome is that it seems to imply that regions ought to be defined so narrowly that every minor pocket of unemployment arising from labor immobility would be counted as a separate region, each of which would have a separate currency. What, then, would impose a limit on the degree of Balkanization? Mundell argues that it would be the transactions costs associated with the maintenance of many currency areas. The point is that money as a medium of exchange is less useful if there are many currencies. Transactions costs will loom especially large under either unconvertibility or flexible exchange rates, with the result that the convenience value of money restricts the optimum number of currencies.[2]

McKinnon extends this theory on optimal currency areas by noting that, in an open economy, the maintenance of balanced international payments has to be added to the factors of domestic price stability and unemployment as a criterion guiding economic policy. The issue in this case is the trade-off between the effectiveness of flexible exchange rates in maintaining the ex-

[2] Additional factors that inhibit the creation of an arbitrarily large number of currency areas, according to Mundell, include the need for a robust foreign exchange market and a currency area sufficiently large that workers accept reductions in their real wage by means of a change in currency values rather than through changes in nominal wages.

ternal balance versus stability in the domestic price level as one moves across the spectrum from closed to more open economies.

This is about as far as the theory of optimal currency areas goes. (For additional material on optimal currency areas, see Tower and Willett.) This has not been a high priority issue among those interested in the monetary aspects of international trade because in the past the tendency has been to take existing national boundaries as sacrosanct. This may be changing, as the events in Yugoslavia, in other countries of Eastern and Central Europe, and in the Soviet Union illustrate. The dollarization of countries in Latin America and other parts of the world when domestic monetary and fiscal policies get out of control, and the seeming economic irrationality of national boundaries in Africa, which were originally defined along the borders of colonialist enclaves, all serve to bring these issues to the fore. With the growing mobility of both capital and labor across what were previously national boundaries, the issue of the optimal economic size for a country may increasingly come to be an important policy issue.

Recent developments in the theory of economic geography also offer some important insights into the size and scope of national countries, especially as one considers the emergence of city-states as one possible limit to the degree of Balkanization that might emerge in response to the shift to optimal currency areas. Krugman develops a simple model that shows how a country can endogenously become differentiated into an industrialized "core" and an agricultural "periphery." This paper is important because it helps to explain one of the most widespread occurrences in the international economy, the tendency of economic activity to congregate into large urban-industrial agglomerations, with a drainage of people from the rural hinterlands.

In the Krugman model, manufacturing firms tend to locate in the region with the larger demand and in order to realize scale economies while minimizing transportation costs. The location of demand itself, however, depends on the distribution of manufacturing activities. This helps explain why parts of a country, or particular cities, which gain an initial impulse toward industrialization tend to maintain their leadership position. The emergence of a core-periphery pattern, in the Krugman model, depends on transportation costs, economies of scale, and the share of manufacturing in national income.

In assessing the empirical relevance of the Krugman model, one needs to keep in mind that much of the economic agglomeration one sees around the world results from large implicit subsidies which favor this tendency and the general tendency of governments to underinvest in the physical infrastructure in rural areas. In commenting on an earlier version of this paper, Gale Johnson noted that Taiwan has avoided such agglomerations in large part because it has invested heavily in the rural infrastructure for national security reasons.

Whether such "core"-"periphery" economies should eventually emerge into a "country" whose sovereignty is defined by a currency would also seem to depend on a number of other issues. The first is whether it tends to take on a particular cultural identity that members decide is worth preserving. The second is the extent to which such a complex should be self-sufficient in an economic sense. If it should evolve toward self-sufficiency, then the transaction costs involved in relating to other currency areas would be minimal, and the emergence of a "national" identity would tend to dominate, tempered, of course, by the extent to which modern communications keep a common and unique culture from emerging.

What can we say about the tendency towards self-sufficiency? Yang and Borland provide insights into this question by addressing the issue of specialization with a dynamic general equilibrium model. These authors build on recent work which allows the sources of economic growth to be endogenously determined. They note that by formalizing a trade-off between the allocation of resources to current consumption, the production of knowledge, and investment in physical capital, a number of studies have established a role for endogenous accumulation in generating economic growth. They cite as examples the work of Romer (1986a, 1989), Lucas, and Aghion and Howitt, in which the rate of growth depends on the endogenous accumulation of human capital and technical change; and additional work by Romer (1986b) and by Grossman and Helpman in which endogenous increases in the number of intermediate inputs (which raise productivity in the production of final goods) explain economic growth.

Yang and Borland note that "by interpreting an expanding range of intermediate inputs to represent a greater division of labor, these latter studies have initiated a formal analysis of Adam Smith's (1776) and Allyn Young's (1928) proposition that increases in the division of labor will create economic growth. However, division of

labor is based not only on an expanding range of intermediate inputs but also on increases in the level of specialization of individual agents." In their paper, Yang and Borland investigate this second aspect of the division of labor and take up the issue of the relationship between the evolution of the level of specialization and economic growth.

Contrary to models which exogenously fix the level of specialization of an individual agent, the Yang-Borland model can explain why an economy evolves from autarky (each person self-produces all the goods he or she wants) to a state in which there is a highly developed division of labor between individuals in a firm, among firms, and among countries. Moreover, the evolution of the division of labor they examine enlarges the extent of the market, speeds up the accumulation of human capital, and raises trade dependence and endogenous comparative advantage. In their view, as long as the division of labor has evolved to a sufficient degree and the potential for further division of labor remains, per capita income will continue to increase over time.

What we witness in the international economy is an increasing degree of specialization and division of labor. This is evidenced in the growth of trade itself, relative to global GNP, but also in the growing importance of international industries, with the parts for a final product produced in a wide variety of countries and resulting in a growing amount of intrafirm trade across national boundaries.

It would seem that this process will continue and even accelerate into the future on the grounds of both Krugman's model and that of Yang and Borland. The drive for increases in per capita income is a strong drive, and the potential for continued economic growth continues to expand as additions are made to the stock of knowledge and as general education spreads around the world. This suggests that what the world is evolving toward is a one-currency world which is highly integrated through international trade, international capital markets, and international migration of labor. Moreover, national economies, however they are defined, can be expected to become increasingly open.

Tamura gives us a model which explains why we can expect per capita incomes to converge in such an increasingly open international economy. Briefly, his model explains how a spillover effect of human capital in the investment technology provides human agents with below-average human capital endowments with a higher rate of return on investment than that received by agents with above-average human capital endowments. Thus below-average human capital agents tend to grow faster than above-average human capital agents. This model explains income convergence of the developed world, regional income convergence within the United States, and intergenerational mobility. It also suggests that optimal currency area issues may not be a major factor influencing the configuration of the future international economy.

Implications

The above discussion has a number of important implications for economic policy and for educational, research, and extension programs. In the first place, it suggests that we can expect general economic integration to continue to spread and, perhaps, at a faster pace than in the past. That means that "national" or regional economies can be expected to become more open over time, and that the bifurcation of economic policy making and implementation will continue into the foreseeable future.

Such a development has a number of important implications for institutional design. For one thing, it means that we need to give more attention to the design of more effective and efficient international institutions. High on the priority list should be a reform of international monetary arrangements. (For detail on how these might be redesigned, see Schuh 1986.) In this context it should be noted that a generalized flexible exchange rate system with neutral monetary and fiscal policies will be equivalent to a one-currency system without the elimination of national currencies.

Highest on the priority list should be the establishment of generalized floating, except in those cases in which it is decided to go to a single-currency system, as appears to be likely in the case of the European Community. Much concern is expressed about the instability of exchange rates, with many people suggesting the return to a system of fixed exchange rates as the means to avoid that instability. In my view that misses the point. Given the size of international financial flows, the world could not go back to a system of fixed exchange rates even if it wanted to. Moreover, the issue is not short-term instability, as often seems to be implied. The basic instability problem is the long swings in the values of real exchange rates the present system is producing. That seems to be generated more by

the present fixity in the system than by the flexibility. With generalized floating, adjustments to external shocks would begin immediately, rather than be delayed until pressures had built up to irresistable levels. Moreover, adjustments would be widespread in the economy, and thus the swings in the exchange rates necessary to restore equilibrium would in general be modest.

Similarly, a great deal of design work is needed on state and local institutions. This may, in fact, be the most pressing need. Along with that endeavor, much work is needed to design a fiscal system which captures resources nationally and transfers an important share of the revenue to the state and local level. The design of such a system is not as easy as it might seem, for when spending is disconnected from taxing, the tendency is to convert the system into a spending machine. The state of Minnesota, for example, has discovered this problem to its horror with its state tax and local government aid systems.

More generally, there are serious questions as to whether our present institutional arrangements are up to handling the bifurcation of economic policy. Public goods in the form of roads, communication systems, education, hospitals, environmental "purity," and so on appear to be increasingly important as the means of attracting economic activity. Equality of opportunity for the sexes means that labor markets are more important in determining where households locate than they have been in the past. Hence, instruments of public policy that address these types of goods are becoming increasingly important.

These issues are of the highest importance to agriculture, both at the international and at the state and local level. At the international level, the failure to reform international monetary arrangements has contributed to instability in commodity markets and to the masking of underlying comparative advantage as a consequence of large swings in real exchange rates. These large swings also contribute to protectionist pressures and make the liberalization of trade in agricultural commodities more difficult.

The development of new institutional arrangements at the state and local level is also especially important for agriculture. Income and adjustment problems will need to be addressed increasingly at this level, as will environmental and other resource-based problems. In the developing countries, locally funded research and education systems will be increasingly important.

At the same time, the generation of public revenue to support these public goods is a major challenge. The widespread financial difficulties state-supported public universities in this country are now facing seem to be related to the failure of local fiscal systems to keep up with their ever-larger responsibilities. The design of new institutional arrangements is an imperative, not only at the state and local level, but at the national and international level as well.

Concluding Comments

The global economy experienced a period of unprecedented economic growth in the late 1960s and through the 1970s, the period of what has been described as the golden era of trade. Even the developing countries experienced the highest rates of economic growth in their history during this period, even though some are poorer today than they were at the end of the 1970s.

What we are experiencing, despite the difficulties of the 1980s, are attempts by countries to gain from trade; that is, to gain from specialization and the international division of labor. Countries are becoming increasingly dependent on the implicit social contract of the world market. Whether the international economy and political system will become more or less stable as we move to the future will depend importantly on how well we manage this common public good. But how well we manage that public good will also depend in an important way on how well we manage the institutional design questions in our domestic economies.

References

Aghion, Philippe, and Peter Howitt. "A Model of Growth through Creative Destruction." Cambridge MA: National Bureau of Economic Research Work. Pap. No. 3223, Jan. 1990.

Commission on U.S.–Japan Relations for the Twenty-First Century. *Preparing for a Pacific Century*. Papers for a "Conference to Explore the Potential for Pacific Basin Cooperation." Washington DC, 6–17 July 1991.

Corbo, V. *Problems, Development Theory, and Strategies of Latin America*. Washington DC: World Bank, Develop. Res. Dep. Rep. No. DRD 190, 1986.

Grossman, Gene M., and Elhanan Helpman. "Comparative Advantage and Long-Run Growth. Cambridge MA: National Bureau of Economic Research Work. Pap. No. 2809, Jan. 1989.

Krugman, Paul. "Increasing Returns and Economic Geography." *J. Polit. Econ.* 99(1991):483–99.

Lucas, Robert E., Jr. "On the Mechanics of Economic Development. *J. Monetary Econ.* 22(1988):3–24.

McKinnon, Ronald I. "Optimum Currency Areas." *Amer.*

Econ. Rev. 53(1963):717–25.
Mundell, Robert A. "A Theory of Optimal Currency Areas." *Amer. Econ. Rev.* 51(1961):657–65.
Romer, Paul M. "Increasing Returns and Long-Run Growth." *J. Polit. Econ.* 94(1986a):1002–37.
——. "Increasing Returns and New Developments in the Theory of Growth." Cambridge MA: National Bureau of Economic Research Work. Pap. No. 3098, Sep. 1989.
——. Increasing Returns, Specialization, and External Economics: Growth as Described by Allyn Young." Center for Economic Research Work. Pap. No. 64, University of Rochester, 1986b.
Schuh, G. Edward. "The New Macroeconomics of Agriculture." *Amer. J. Agr. Econ.* 58(1976):802–11.
——. *The United States and the Developing Countries: An Economic Perspective.* Washington DC: National Planning Assoc., 1986.
Schuh, G. Edward, and Antonio Salazar Brandao. "The Theory, Empirical Evidence, and Debates on Agricultural Development Issues in Latin America: A Selective Survey." *A Survey of Agricultural Economics Literature,* ed. Lee Martin. Minneapolis: University of Minnesota Press, forthcoming.
Smith, Adam. *An Inquiry into the Nature and Causes of Nations.* Reprint (1776), ed. Edwin Cannan. Chicago: University of Chicago Press, 1976.
Tamura, Robert. "Income Convergence in an Endogenous Growth Model." *J. Polit. Econ.* 99(1991):460–82.
Tower, Edward, and Thomas D. Willett. *The Theory of Optimum Currency Areas and Exchange Rate Flexibility.* Int. Finan. Sect., Special Papers in Int. Econ. No. 11, Princeton University, 1976.
Yang, Xiaokai, and Jeff Borland. "A Microeconomic Mechanism for Economic Growth." *J. Polit. Econ.* 99(1991):460–82.
Young, Allyn A. "Increasing Returns and Economic Progress." *Econ. J.* 38(1928):527–42.

Frederick V. Waugh Memorial Lecture Program

This year marks the initiation of the Frederick V. Waugh lecture program in commemoration of the professional contributions of Frederick V. Waugh. The program is sponsored by the Economic Research Service, U.S. Department of Agriculture and the American Agricultural Economics Association. The lecture will be presented each year at the annual meeting of the American Agricultural Economics Association and published in the December proceedings issue of the *American Journal of Agricultural Economics*. The following two papers are an introduction to Frederick V. Waugh and review of his professional career by James P. Houck and the inaugural lecture presented by Marc Nerlove.

Sound Judgment and Common Sense: The Professional Legacy of Fred Waugh

James P. Houck

"Whatever tools are used, there is no substitute for sound judgement and common sense. Without this, the economist is going to get into trouble. . . ."

—F. V. Waugh (July 1957, p. 1)

If he were here today, Fred Waugh surely would be feeling self-conscious if not downright embarrassed by all of this personal attention. Even so, I know that many, many people join me in thanking the Economic Research Service (ERS) and the American Agricultural Economics Association (AAEA) for establishing this Memorial Lecture Series in Fred's name. Its goals are simple—to commemorate Fred Waugh's unique contributions to agricultural economics and its related professions and to recognize recent work that continues his special tradition of real-world relevance and imagination.

Frederick Vail Waugh was one of the great pioneers in agricultural economics. His career, mostly with the U.S. Department of Agriculture (USDA), spanned more than fifty years, from the early 1920s to the mid-1970s. This was a zesty period when agricultural economics emerged as a separate, special field of applied economics. That agricultural economics developed a rich tradition in the practical use of economic theory, mathematics, statistics, and econometrics is largely because of work by Fred Waugh and the many colleagues he inspired and encouraged.

Waugh was uncommon in his ability to weave theory, mathematics, and statistics into economic analysis. And his special knack was to do this with clarity, simplicity, and style. For all his innovativeness in bringing several disciplines together, real-world relevance was a consistent Waugh trademark. Here are just a few currently relevant topics on which Fred Waugh broke new intellectual and empirical ground: the optimal allocation of product sales among separate markets, subsidized food stamps for low-income people, the usefulness of price stability for agricultural products, the size and composition of grain reserve stocks, linear program-

James P. Houck is a professor and Head of the Department of Agricultural and Applied Economics, University of Minnesota.

This paper was presented at the first Frederick V. Waugh Memorial Lecture Program, 7 Aug. 1991, in Manhattan, Kansas.

This paper draws heavily upon material prepared by James P. Houck and Martin Abel for the introduction to a collection of Waugh's writings published by the University of Minnesota Press in 1984.

ming as a tool for economic analysis, and the causes and measurement of cyclical behavior in farm output and prices. Illuminating public policy issues in food and agriculture was one of Waugh's numerous gifts. References to Waugh's published work still appear routinely in even the most recent policy analyses as well as in the technical writings of agricultural economists and econometricians.

Much of his work was done in the 1930s, 1940s, and 1950s, before most of today's agricultural and general economists were active. These early writings may seem unsophisticated by present-day standards. Yet, he was searching out and developing those very analytical techniques which now are commonplace. Another reason that Waugh's work often seems disarmingly simple is that it was the product of unique insight and extraordinarily clear exposition. For those interested, a selection of twenty-nine of Waugh's writings and a nearly complete bibliography of his published work is contained in the referenced volume *Selected Writings on Agricultural Policy and Economic Analysis: Frederick V. Waugh* (1984), pp. 451–55.

Fred Waugh was also known for his special teaching skills. His formal teaching included brief stints at Cornell University, the Brookings Institution, and the USDA Graduate School. His informal instruction skills were legendary in seminars, impromptu discussions in offices and hallways, memos, letters, committee meetings, and the writing of new teaching material. For example, in the late 1930s, Waugh saw clearly that economists who really wanted to understand economic statistics and econometrics should grasp matrix algebra. A textbook to his liking was not available, so he wrote one. Although never formally published, it was mimeographed and used extensively within the USDA. No doubt, a few copies still slumber in neglected file drawers at ERS headquarters.

Today's middle-aged agricultural economists who knew Fred Waugh, if only casually, remember him as an elder statesman, a wise colleague, always willing and eager to meet younger economists and engage them in professional exchange. His natural traits of patience, tact, graciousness, and good humor bloomed equally with fledgling analysts and seasoned bureaucrats.

Frederick V. Waugh was born in Burlington, Vermont, in 1898. He obtained his B.S. degree in 1922 from Massachusetts Agricultural College, his education having been delayed two years by World War I service in France, where he was awarded the Croix de Guerre medal. He received his M.S. degree from Rutgers in 1924. Intermittent graduate work followed at Columbia and Harvard universities, culminating with the Ph.D. degree in 1929 from Columbia, where he studied under Frederick C. Mills. His published doctoral dissertation, *Quality as a Determinant of Vegetable Prices,* was a path-breaking blend of theory and statistics applied to a real-world problem.

Waugh was intrigued by the potential integration of economic theory, mathematics, and statistics as the way to unlock answers to practical problems in economic research and forecasting. He was much influenced in the 1920s by the new ideas of Columbia University's Henry L. Moore and later by those of Holbrook and Elmer Working. Waugh also drew inspiration from Henry Schultz, a disciple of Moore's, whose pioneering work is a clear benchmark in the development of statistical economics and demand measurement.

In 1923–24, a young Fred Waugh applied then-novel statistical techniques to analyze potato prices while he was with the New Jersey Department of Agriculture. His interests in these methods continued to ferment and evolve during service with the Connecticut Agriculture Extension Service (1925–26), the Massachusetts Division of Markets (1926–28), and the New England Research Council (1928–32).

In 1932 and 1933, Waugh traveled to Europe on a Social Science Research Council fellowship to strengthen his understanding of economic theory and its relation to empirical research. Before leaving, he wrote to the well-known regression and correlation statistician, Mordecai Ezekiel, seeking advice about whom to study with. Ezekiel's advice was not encouraging: "So far as I know you will not learn anything in Europe on any of the topics you suggest." Ezekiel encouraged Waugh to stay in the United States and work with Wassily Leontief, then in New York, Irving Fisher at Yale, and Henry Schultz at the University of Chicago.

Waugh was undaunted by this advice. He replied to Ezekiel, "It has seemed to me that we are getting divided into two groups—theoretical economists and statisticians—neither group being much interested in the other, except that you, the Working brothers, and (Henry) Schultz have discussed some theoretical considerations. I am interested in the possibility of building up an economic value theory along the lines of the French mathematical school but illustrated by—and perhaps largely based on—observed relationships.

"I am, therefore, only incidentally interested in statistical technique, although I want to get hold of anything new and worthwhile. I would particularly like to get a better understanding of the mathematical theory of value and suppose that, except for Fisher, the best men in this line are in Europe."

While in Europe, Waugh spent most of his time with Ragnar Frisch in Norway. He also worked with Erich Schneider in Germany, François Divisia in France, and Jan Tinbergen in the Netherlands. This experience had a profound impact on his future work. It gave him much of what he sought—the blending of theory and quantitative techniques for the analysis of relevant economic problems.

From 1932 to 1945, Waugh worked in various agencies of the U.S. Department of Agriculture. In the mid-1930s he developed a formal theory of price discrimination among separate markets. He used this theory to confront a real problem of the time that puzzled and bothered him—the side-by-side existence of food surpluses and hungry people. In a 1938 *Journal of Farm Economics* article, "Market Prorates and Social Welfare," Waugh demonstrated that a graduated food-pricing program could be used to increase total food consumption among poor people and reduce surpluses without damaging farm income. The article quickly attracted the attention of politicians and USDA officials. Waugh's proposal evolved into the first Food Stamp Program. This program provided subsidized food to the poor, operating on a large-scale trial basis from 1939 until World War II. Later he provided much advice for the experimental Food Stamp Program of 1961, which matured into today's massive government program which provides food for America's poor.

During 1945–46, he served as adviser to the Office of War Mobilization and Reconversion. From there, he moved to the newly formed President's Council of Economic Advisers, where he was the senior staff member for agriculture from 1946 to 1951. He then returned to the USDA, remaining there until retirement in 1965. After retiring, Waugh remained active as a consultant to the USDA, the Food and Agriculture Organization of the United Nations, the National Advisory Commission on Food and Fiber, and the Department of Commerce.

In the 1950s, Waugh, working with the USDA's James P. Cavin, recruited a group of young economists to develop new econometric techniques and apply them to agricultural commodities. These analysts, under the leadership of Karl A. Fox, fashioned and applied modern econometric techniques to the study of agricultural markets. In fact, this imaginative work clearly set the pace for applied econometric work across the entire economics profession. These path-breaking studies probed the demand and price structure of virtually all major farm commodities: wheat, feeds and feed grains, meat and livestock, fats, oils, and oilseeds, vegetables, eggs, and dairy products.

The numerous bulletins published from this work, informally dubbed "the demand and price structure series," were standard references on the techniques of applied econometrics until appropriate textbooks became available. Of particular importance was the broad application of then-novel techniques of simultaneous equation estimation and analyses. Many researchers in this group became distinguished senior economists in government, universities, and private industry. To a person, they credit Fred Waugh with establishing and maintaining the intellectual and administrative environment within which this remarkable burst of creativity occurred.

Waugh was a vigorous proponent of simple graphic data analysis as a first step in most economic inquiries. He wrote three popular USDA handbooks on this topic in 1955, 1957, and 1966. Waugh urged, "Use graphics in the preliminary analysis of a problem, then more elaborate mathematical methods to pin down results with greater precision." He would have been absolutely delighted with the ability of modern personal computers to create and maneuver graphics but dismayed, perhaps, at the ease with which hastily conceived statistical analyses can be generated and dispensed.

Waugh's interests stretched well beyond agricultural economics and statistics. But, unlike most of us, he wrote and published papers about his hobbies—probabilities in the game of bridge, early mathematical discoveries of Greeks and Romans, and the cutting and polishing of gem stones. In 1957, he published, in the *Lapidary Journal,* an original design for cutting diamonds, quartz, topaz, or beryl and called it "The Sparkler Cut." Although it never became more than an historical curiosity in the lapidary world, the name surely reflects the intellectual character of its uncommon inventor.

Fred Waugh came by his peripatetic interests quite naturally. They were commonplace in his remarkable family. For example, Fred's father, Frank Albert Waugh, was a noted landscape architect who taught for many years at the University of Massachusetts, Amherst. Although the

senior Waugh wrote extensively on landscape design and related topics, he also found time to produce a whimsical book in 1942 entitled *Home Pork Production* under the pen name, John Smedley. Similarly, Fred's brother, Albert E. Waugh, a successful and well-published statistician and economist at the University of Connecticut, wrote a book in 1973 titled *Sundials: Their Theory and Construction.* Any serious biographer of Fred Waugh will surely find a rich vein of fascinating material running through this singular family.

Frederick Waugh was recognized frequently by his colleagues for outstanding achievements. He was vice-president and president of the American Farm Economic Association (now the AAEA) in 1939 and 1946, respectively. He also served as vice-president of the American Statistical Association in 1941. He was named Fellow of both the American Farm Economic Association and the American Statistical Association. He was a charter member and Fellow of the Econometric Society. On three separate occasions, publications by Waugh were selected as "Outstanding Journal Articles" in the annual award program conducted by the American Farm Economic Association in 1956 for "A Partial Indifference Surface for Beef and Pork," in 1961 for "Advertising without Supply Control: Some Implications of a Study of Advertising in Oranges" (co-authored with Marc Nerlove), and in 1964 for "Cobweb Models." In 1974, his 1969 USDA Technical Bulletin, *Demand and Price Analysis: Some Examples from Agriculture,* was named as that year's "Publication of Enduring Quality" by the Awards Committee of the AAEA. In his 1988 *CHOICES* profile on Waugh, Martin Abel wrote (p. 44), "Today's ideas stand on the shoulders of the intellectual giants who preceded us. Fred Waugh was one of those giants."

Frederick V. Waugh died in February 1974. In his life he was an intellectual pioneer and a leader in agricultural economics. He was an innovative and careful craftsman across many professional disciplines. He was a trusted adviser to several generations of agricultural policy leaders. He thought and wrote creatively about numerous topics that remain relevant today. He left a valuable legacy which is reflected in his writings, the work of many colleagues, and in this Memorial Lecture Program. He was a wise and modest man.

References

Abel, Martin E. "Frederick V. Waugh: A Profile of Relevance." *CHOICES,* no. 4 (1988), pp. 42–44.

Smedley, John (pseud. of Frank Albert Waugh). *Home Pork Production.* New York: Orange Judd Publishing Co., 1942.

Waugh, Albert E. *Sundials: Their Theory and Construction.* New York City: Dover Publications, 1973.

Waugh, Frederick V. *Graphic Analysis in Agricultural Economics.* Washington DC: U.S. Department of Agriculture, Agr. Mktg. Serv. Agr. Handbook No. 128, July 1957.

——. *Selected Writings on Agricultural Policy and Economic Analysis,* ed. James P. Houck and Martin E. Abel. Minneapolis: University of Minnesota Press, 1984.

——. "The Sparkler Cut." *Lapidary J.,* vol. 10, June 1957, pp. 244.

Population and the Environment: A Parable of Firewood and Other Tales

Marc Nerlove

Few issues, it is safe to say, excite as much interest or concern in contemporary economics as those related to environment and to unpriced resources of all kinds. At bottom, many long-term environmental problems, whether they derive proximately from use of modern agricultural technology to augment food production or too rapid exploitation of exhaustible energy and other natural resources, stem ultimately from the pressure of human population and human desires for subsistence, if not greater, levels of creature comforts. Economists and others are acutely aware of the role which population pressure plays in causing environmental degradation in developing countries and, since Hardin's justly famous "The Tragedy of the Commons," of how the unpriced or underpriced character of environmental and other natural resources leads to overexploitation and ultimate degradation. The other side of this intellectual coin is the role which environmental degradation and natural resources depletion may play in producing the very same population pressure which lies behind such degradation and depletion especially in developing countries. This role is less widely appreciated and understood.

In this essay I shall focus on this latter aspect of the relation between population and environment. I shall do so in the context of a rather abstract dynamic planar system of two nonlinear difference equations, one of which reflects the way in which population pressure affects the state of the environment of future generations and its evolution over time and the other of which characterizes human fertility behavior in terms of optimization subject to environmental constraints.[1] While there is much to say about how population pressure may affect environment in different environmental and institutional contexts, I shall adopt the not entirely uncontroversial position that it does so adversely, in order to emphasize the way in which human fertility and population growth may react to environmental degradation.

The principal conclusion of this analysis is that the possibilities for a stable equilibrium between human population and its environment are quite limited. Even given a relatively favorable relationship between population pressure and the evolution of environmental degradation over time, a stable equilibrium can be achieved only if fertility responds negatively to environmental degradation and then only if the response is sufficiently large in absolute magnitude in relation to the dynamic response of environment to population pressure. Under exceptionally adverse environmental circumstances, rising death rates can ultimately bring a halt to further environmental deterioration and/or lead to human extinction.

Unfortunately, there are ample reasons to suppose that in much of the Third World fertility is likely to react positively to increasing environmental degradation because parents perceive the benefits of having more children to be higher under environmentally more adverse cir-

Frederick V. Waugh Memorial Lecture

Marc Nerlove is a professor in the Department of Economics, University of Pennsylvania.

This paper is based on earlier work joint with Anke Meyer and with the able research assistance of Viktória Dalkó. It has been supported by the International Food Policy Research Institute, Washington, D.C.

The author is also indebted to Christain Gourieroux, Heinz Koenig, and Efraim Sadka for helpful discussions in connection with a number of previous drafts.

[1] Analysis of the dynamics of planar systems is discussed in an appendix to this lecture available from the author on request. Many important economic problems can be cast in the form of a planar system, the mathematics of which is now becoming known among mathematical economists (Grandmont). Basic references are Guckenheimer and Holmes and Iooss and Joseph. A more complete exposition of the dynamics of planar systems with applications to population, environmental, and natural resource economics is currently in preparation.

One important characteristic of problems in the economics of natural resources, shared by the analysis of the present lecture, is that the economic decision making is one sided: exploitation of resources, population growth, or similar variables are the result of human behavioral processes, whereas the regeneration or degradation of the resource is subject to natural law. Clearly, it is possible to imagine situations in which this need not be the case, for example, if investment can be made to ameliorate the adverse effects on environment caused by population growth.

cumstances than under more favorable ones. For example, if the probability of a child surviving to adulthood and thus to care for its parents in their old age is lower in poorer quality environments, parents may be induced to bear greater numbers, which, until infant and child mortality levels rise sufficiently to offset the greater number of births, will generally result in higher, not lower, rates of population growth under environmentally adverse circumstances. Along similar lines, it may be argued that if children participate actively in agricultural production in the Third World, their comparative advantage is enhanced relative to adults in poor environments because animal husbandry supplants crop production, where children arguably have less advantage in the heavy work of tilling and harvesting than they have in herding livestock.

This theme is developed at some length in a series of metaphors based on a two-period overlapping generations (OLG) model, in which parents value children solely for the contribution they may make to their own selfishly perceived welfare. Notwithstanding, it is possible to argue that, as environment deteriorates, the relationship between the state of environmental degradation and the rate of population growth must eventually turn from positive to negative; that is, further deterioration in the state of the environment will be accompanied by a lesser rate of growth of population, thus opening the way to a stable, albeit possibly unpleasant, equilibrium between population and environment.

While one may question the desirability of such an equilibrium from some grand and humane ethical view, altruism or love is perhaps a luxury in which only the relatively well-off can afford to indulge. In any case, I do not believe in the efficacy of addressing such issues from any point of view other than that of the present generation. The reason we care about environmental deterioration as it affects future generations is precisely because we care about the welfare of our own children and possibly those of others. Without introducing altruism or love in some manner, we cannot hope to make precise the welfare losses which result from excessive population growth leading to environmental deterioration. And, in a two-period OLG model without altruism, there is no scope for a discussion of welfare losses to the present generation resulting from the unpriced character of environmental and natural resources because those members of the present generation are no longer around to experience the effects of environmental deterioration and do not care about their children's welfare.[2]

Next, in the context of a metaphor in which the perceived benefits of having children relate to their role in agricultural production, which I call "a parable of firewood," I show that parental altruism toward their children can only make matters worse, if socially unchecked, by leading to an increase of the birthrate in every environmental state in comparison with that which would occur in its absence.[3] In other words, love is not enough to lead to stability and may even result in a worse outcome for members of the current present generation over time than in its absence. Nonetheless, love in the sense of parental concern for the future welfare of their offspring, opens the door to social intervention. This is because environmental quality being an unpriced resource does not enter into individual parents' calculation of the costs and benefits of having additional children.

The failure of laissez-faire to attain a Pareto-optimal situation for members of the present generation represents an externality, the usual theoretical remedy for which is a system of Pigouvian taxes and subsidies which force parents to internalize the true social costs and benefits of having additional children. In other words, the unpriced nature of environmental resources drives a wedge between the marginal social cost and the marginal private cost of a child for the parents which a per capita tax on children accompanied by a lump sum payment to parents of the social total of the proceeds might correct.

The next step in the analysis is to see how a tax on children repaid lump sum to parents will change the equilibrium birthrate for a given level

---

[2] There is also no scope for bequests in the form of physical capital which, in this context, could take the form of investments in "clean-up" facilities or other projects designed to improve future environmental quality. It should also be noted that the metaphors explored here assume no adverse environmental effects of population pressure on the present generation, i.e., their environment is what it is and they can do nothing to affect it.

[3] This is in part a consequence of the neglect of possibilities for investment in the human capital of children to improve their future welfare, or in bequests in the form of physical capital. If such possibilities were introduced along with parental altruism, improvements in the rates of return associated with bequests would act to cause parents to substitute away from child numbers towards child "quality." In an early paper (Nerlove) I offered this as one explanation of the so-called "demographic transition," since, arguably, falling infant, child, and adult mortality enhances the rate of return to investment in human capital (because such capital dies with its owner). Increasing bequests in the form of human capital act, à la Becker-Lewis, to augment the "price" of additional child numbers leading parents, *ceteris paribus*, to substitute "quality" for "quantity."

of environmental quality with or without altruism. In general, it is possible to design such a tax/subsidy scheme to achieve any desired birth rate including one which might stabilize the equilibrium between population and the environment. This leads naturally to the question of what a Pareto-optimal birthrate from the standpoint of the present generation might be. Unfortunately, determination of such a rate depends crucially on parents' beliefs about the future states of the environment as well as the degree to which they weight their children's welfare in their private calculation of costs and benefits. Except in a state of stationary equilibrium, it is unreasonable to suppose that such beliefs reflect reality with any degree of accuracy. This observation, then, leads naturally to a welfare comparison between two or more steady states occuring at different levels of environmental degradation. It is easy to argue that each member of the present generation will be better off at an equilibrium with better environmental quality than at one of lesser quality. What is not so clear is that members of the present generation would be better off at such an equilibrium than in a nonequilibrium and possibly unstable situation. On this pessimistic note I close.[4]

The plan of the remainder of the paper is as follows: In the second section the two-equation OLG model of population and the environment is established and the questions of the existence and local stability of steady-state solutions are addressed, with some remarks on the global evolution of the system. Mathematical details are relegated to an appendix on the dynamics of planar systems available from the author on request. In the third section, the focus shifts to the relation between environment and population when fertility is endogenously determined to maximize parents' utility from surviving children. I argue that an absolute limit to the number of children a woman can have in her lifetime will ultimately reduce the rate of growth of population if survival probabilities decline sufficiently, even if the number of births continues to rise. The manner in which children generate utility for their parents is taken up in the fourth section, in which a similar conclusion follows even when survival probability is assumed to be unaffected by environmental quality. Taxes and subsidies which can achieve and maintain a given birthrate then are introduced. Parental altruism is introduced and shown to lead to a higher birthrate than would occur in its absence for any given state of environmental quality. Although altruism generally leads to a failure to achieve a Pareto optimum from the standpoint of the present generation, it is difficult to specify such an optimum. The paper concludes with some remarks about the possibility of investment in human and physical capital to improve the welfare of future generations and ameliorate the effects of population pressure on environment.

The Dynamics of Population and Environment When Fertility Is Endogenous

Consider a two-period overlapping-generations (OLG) model in which people live as children in the first period. At the end of the first period, they reproduce in order to maximize their utility of life in the next period as adults, a utility which may or may not reflect concern for the future welfare of their offspring. Their decisions are assumed to reflect their perception of the state of the environment. To avoid the complications of sexual reproduction and marriage, reproduction is assumed to occur by parthenogenesis.

Let Z_t represent the state of the environmental degradation at time t. Thus, the larger Z_t, the lower the level of environmental quality. Let N_t be the number of children alive at the end of period t who instantly become parents at that moment. The current state of the environment is assumed to depend only on its state in the previous period, as that interacts with that part of the population who are then children:

$$(2.1) \qquad Z_t = g(Z_{t-1}, N_{t-1}),$$

where $\partial g/\partial Z_{t-1} > 0$ and $\partial g/\partial N_{t-1} > 0$.[5] The assumption that $\partial g/\partial N > 0$ is not uncontroversial. It has been suggested (McNicholl; Jodha;

[4] Less pessimistic conclusions would likely result from the introduction of the possibilities of investment in human and physical capital together with parental altruism (see the previous footnote). Models with such possibilities will be explored in subsequent research.

[5] In an earlier formulation (Nerlove and Meyer 1990), we assumed more specifically that g was of such a form that

$$(2.1^*) \qquad Z_t/Z_{t-1} = g^*(N_{t-1}).$$

Taking logs, it is easy to see that this implies

$$\xi_Z = \frac{\partial g}{\partial Z_{t-1}} \frac{Z_{t-1}}{Z_t} = 1.$$

Our more specialized assumption was motivated largely by a desire to facilitate a graphical determination of global trajectories. Unfortunately, $\xi_Z = 1$ virtually guarantees local instability of any stationary point.

Simon, pp. 82–107) that in certain types of environments, given the proper institutional and social organization, population growth can affect environmental quality favorably. Moreover, such a favorable relationship may be characteristic at low levels of population and relatively high levels of environmental quality, but not when population pressure is great. This is not, however, the stuff of current concerns nor the focus here. A stationary environmental state, if one exists for some level of population size N, is characterized by $Z_t = Z_{t-1} = \bar{Z}$ such that

$$\bar{Z} = g(\bar{Z}, N). \tag{2.2}$$

At such a point, if one exists, the elasticities are defined as

$$\xi_z = \frac{\partial g}{\partial Z}\frac{\bar{Z}}{\bar{Z}} \quad \text{and} \quad \xi_N = \frac{\partial g}{\partial N}\frac{\bar{N}}{\bar{Z}}. \tag{2.3}$$

In the following sections of this paper, the focus is on how family decisions with respect to births, or endogenous fertility, as shaped by environmental circumstances or constraints, relate to the rate of growth of population, N_t/N_{t-1}. It is natural, therefore, to treat this matter on a per family basis so that individual decisions are translated into social outcomes proportionately to the numbers of decision makers. At this point, let me write generally

$$N_t/N_{t-1} = h(Z_{t-1}), \tag{2.4}$$

where h' is to be determined.[6] A stationary population, if one exists for a level of environmental quality $\bar{Z}$, is characterized by $N_t = N_{t-1} = \bar{N}$ such that

$$1 = h(Z). \tag{2.5}$$

Because h may not be monotonic or there may exist no value of Z for which $h(Z) = 1$, equation (2.5) may have multiple solutions, one solution, or no solutions at all. I argue below that plausible models of family decision making and/or the effects of rising death rates with increasing environmental deterioration make it likely that if, for relatively good environmental quality, $h' > 0$, eventually as environment deteriorates $h' < 0$. Thus, if h' changes sign just once, there are either two solutions to (2.5) or none. If a solution exists the elasticities are defined as

$$\eta_Z = h'\bar{Z}/\bar{N} \quad \text{and} \quad \eta_N = h\bar{N}/\bar{N} = 1; \tag{2.6}$$

that is, because of the form of the relation between the current level of population, its past value, and environmental quality, η_N is always 1 at a stationary population level. This fact plays a crucial role in further analysis.

In order for a stationary solution, in which both population and environmental quality are unchanging, to exist, points $(\bar{Z}, \bar{N})$ must exist for which (2.2) and (2.5) simultaneously hold:

$$\bar{Z} = g(\bar{Z}, \bar{N}) \quad \text{and} \quad 1 = h(\bar{Z}). \tag{2.7}$$

Clearly, even if solutions to (2.5) exist, none may be characterized by $\bar{N}$ such that (2.2) holds. The opposite is not true, however; any solution to (2.2) must be characterized by unchanging N, except possibly when the function g is pathological. The appendix shows how to find stationary points graphically, if they exist, and how to determine points along the trajectory beginning from any other point. Here, the only comment is that if $\xi_Z = 1$, a property which will guarantee local instability of any stationary points which may exist, then it is easy to impose plausible conditions on g which guarantee a simultaneous solution $(\bar{Z}, \bar{N})$ to (2.7).

Equations (2.1) and (2.4) constitute a system of two nonlinear difference equations which determine the trajectories of the two variables Z_t and N_t starting from some initial value (Z_0, N_0) and subject to some boundary conditions, a so-called planar system. Systems of nonlinear difference equations may be analyzed qualitatively in the vicinity of a stationary point $(\bar{Z}, \bar{N})$ by standard methods. See, for example, Iooss and Joseph (chap. 4, pp. 42–58). Analysis of global behavior is considerably more difficult and can be exceedingly complex (Guckenheimer and Holmes). The appendix contains a complete analysis of the local dynamics of planar systems with application to the system (2.1) and (2.4) and some remarks on global properties, including the diagrammatic analysis referred to above. The discussion of global dynamics also serves to illustrate how the existence of stationary points may be determined.

The general analysis of local stability is supplemented by an analysis incorporating the special assumptions concerning the functions g and h in (2.1) and (2.4). These are that at a stationary point $(\bar{Z}, \bar{N})$, if one exists,

$$\xi_Z > 0$$
$$\xi_N > 0$$

[6] In Nerlove and Meyer (1991), we made family decisions at the end of period $t - 1$ depend on environmental quality in period t:

$$\frac{N_t}{N_{t-1}} = h^*(Z_t). \tag{2.4*}$$

This only complicates the algebra without adding anything essential to the analysis.

η_Z may be either positive or negative
$\eta_N = 1$.

The analysis shows that, if $\xi_Z \geq 1$, no stationary point can ever be locally stable. Consequently, in studying the possibility of a locally stable solution, we can rule this case out and assume $\xi_Z < 1$. The analysis then yields the following conclusions:

PROPOSITION 1. *If, at a stationary point $S = (\bar{Z}, \bar{N})$, $\eta_Z > 0$, i.e., the rate of change of population responds positively to environmental deterioration, the point S is unstable. It is an unstable saddle when*

$$\xi_N\eta_Z < 2(1 + \xi_Z)$$

and an unstable source when

$$\xi_N\eta_Z > 2(1 + \xi_Z).$$

Discussion. Because we have already restricted consideration to the range $0 < \xi_Z < 1$, the bound on $\xi_N\eta_Z$ is a number between 2 and 4. Thus, which type of instability we encounter when $\xi_N > 0$ and $\eta_Z > 0$ depends on how responsive environmental quality is to population pressure. If it is relatively unresponsive, the rate of growth of population can be more responsive to environmental deterioration and still yield a locally unstable saddle rather than an unstable source.

PROPOSITION 2. *If, at a stationary point S, $\eta_Z < 0$, it is possible that S is stable.*

Discussion. I will argue in the next section that if $\eta_Z > 0$ at low levels of Z, that is relatively good environments, η_Z is likely to fall and eventually become negative, thus opening up the possibility that there exists another stationary point with a larger population and a poorer environment which is a stable equilibrium of the system. The argument is based on the fact that there is some fixed upper bound to the number of children a woman can have. In the following section, a similar argument is given based on the presumption that environmental quality becomes more like an ordinary factor of production, in the sense that deterioration reduces rather than enhances the perceived benefits of having additional children, when environmental quality becomes sufficiently bad.

PROPOSITION 3. *Even when $\eta_Z < 0$ at a stationary point S, if*

$$\xi_Z - \xi_N\eta_Z > 1$$

or, put another way, since $0 < \xi_Z < 1$ and $\xi_N > 0$, $\eta_Z < 0$, when

$$\xi_N(-\eta_Z) > 1 - \xi_Z > 0,$$

S is an unstable spiral. Otherwise S is a stable spiral node or a stable simple node depending how small $\xi_N(-\eta_Z)$ is in relation to ξ_Z.

Discussion. Because ξ_Z is bounded between 0 and 1, so is $1 - \xi_Z$. Thus, the possibility that S is stable in either way is reduced as ξ_Z approaches 1. Even under the most favorable of circumstances, stability can be achieved only when

$$\xi_N(-\eta_Z) < 1.$$

Thus if ξ_N is small, η_Z can be larger in absolute value and stability may be attained. If ξ_N is large, however, then the rate of population growth must be rather insensitive to environmental deterioration. The balance is delicate: For any fixed ξ_Z between zero and one, either too large ξ_N or $(-\eta_Z)$ produce instability. In the last section of this paper I show how social intervention in the form of a head tax on children and a lump-sum subsidy to parents can be used to force the system to equilibrium by altering the function h, and thus η_Z, and to maintain it there. But, such intervention may not represent a gain in the welfare of parents even when they are altruistic with respect to their children.

Endogenous Fertility 1: Ensuring Survivors for Old Age Security

In this section, a relation is derived between the rate of growth of population and environmental quality based on a model in which parents determine their fertility in order to maximize the expectation of their utility which is a concave function of the number of surviving children. The optimal number of births can be shown, under rather general circumstances, to be negatively related to the probability of survival which, in turn, is assumed to be related to environmental quality, through the effects of environmental deterioration, pollution, and overcrowding on infant and child mortality. The introduction of *ex ante* costs of births which are positively correlated with the rate of infant and child mortality as well as with the number of actual births may reduce, or even reverse, the sign of the relation between environmental deterioration and the endogenously determined birthrate. But, in any case, the rate of growth of population de-

pends not merely on the optimal birthrate for a particular survival rate which, in turn, depends on the level of environmental quality. It also depends on the elasticity of the birthrate with respect to survival probability. While generally negative, this elasticity must approach zero as environment deteriorates because of an absolute limitation to the number of births a woman can have. This means that if η_Z of the preceding section begins positive, it must eventually become negative. Adult death rates (where death occurs prior to or limits reproduction), which rise as environment deteriorates, have a similar effect.

The assumption of a two-period OLG model with parthenogenesis made in the previous section is maintained. In the first period of life, children support their parents, in the second, each child becomes herself a parent and lives off the fruit of her children's labors. The analysis is an extension of the so-called "old-age security hypothesis" (Neher, T. W. Schultz, Willis). Nerlove, Razin, and Sadka (1987a, b) show that parental altruism may alter the usual conclusion about the way in which means other than children for transfering resources from youth to old age may affect fertility.

It has been argued that lower birthrates are empirically associated with lower infant and child mortality rates, which in turn are associated with generally falling death rates (Freedman; Preston 1976, 1978; T. P. Schultz). Such a relationship serves as a basis for many theories of the so-called demographic transition. Nonetheless, demonstration of the relationship from a simple economic model of fertility choice has proved elusive. Recent theoretical work of Sah, and to a lesser extent the pioneering numerical work of Wolpin, have provided a significant breakthrough in the development of a satisfactory analytical characterization of the observed empirical regularity in terms of the structure of the parent's utility function and the existence of *ex ante* costs. For purposes here, it is assumed that the utility-maximizing parent determines the optimal number of births she has as a function of the probability a birth survives and the *ex ante* marginal costs of births, which may or may not be correlated negatively with child survival probabilities.[7]

[7] In currently ongoing research, Viktória Dalkó and I are exploring 3-period OLG models in which investment in the human capital of children at the expense of parental consumption in the first period of the child's life can enhance the probability that a child will survive to the second period of life to contribute to the support of her parents. This is a way of introducing human capital investments without parental altruism. It also shows the *ex ante* costs are controllable by the parents independently of the number of births.

I will first assume that *ex ante* costs of births are absent and assume that, *ex post*, the parent's utility is a function of the number of surviving children, n_t, which if we assume that children who survive birth also survive to reproduce, is the rate of growth of the number of parents:

$$n_{t-1} = N_t/N_{t-1}. \tag{3.1}$$

After the analysis of this case, I will examine what difference adult deaths prior to reproduction may make and the effects of *ex ante* costs of births.

In this model, however, all births do not survive. If the proportion of survivors is s, then, on average,

$$n_t = sb_t. \tag{3.2}$$

Sah shows that, when utility is a concave function of surviving births and when there are no *ex ante* costs of births or absolute limitations to the number of births a woman can have, the optimal utility-maximizing value of b_t as a function of s is nonincreasing. Sah's proof makes essential use of the discrete nature of the variable b at the individual level. For our purpose, assume that the function which relates the optimal number of births to the survival probability is

$$b = \hat{b}(s) = \hat{b}[s(Z)] = H(Z), \tag{3.3}$$

where $\hat{b}' < 0$ and $s' < 0$, so that $H' > 0$. Here, s is a decreasing function of environmental deterioration. Thus, b is an increasing function of environmental deterioration. Time subscripts have been dropped for simplicity.

From (3.2) it follows that

$$h'(Z) = s'(Z)H(Z)[1 + \sigma(Z)], \tag{3.4}$$

where

$$n = s\hat{b}(s) = s(Z)H(Z) \quad \text{and}$$
$$\sigma(Z) = b'[s(Z)]s(Z)]/b[s(Z)],$$

is the elasticity of births with respect to the survival rate. Because $s' < 0$, $H > 0$, and $\sigma < 0$,

$$h' \lesseqgtr 0 \quad \text{according as} \quad \sigma \lesseqgtr -1. \tag{3.5}$$

Thus, η_Z, the elasticity of the rate of growth of population with respect to environmental deterioration, is positive or negative depending on whether the elasticity of births with respect to the survival rate, which is negative, is greater than or less than one in absolute value. This clearly depends on the shape of the parent's utility function, a matter to be investigated in a particular context in the next section.

What is the effect of adult deaths prior to re-

production on the sign of the derivative of n with respect to environmental deterioration? Suppose that the adult death rate δ is an increasing function of Z. Then

$$(3.6) \qquad dn/dZ = h'(1 - \delta) - h\delta'.$$

Because $0 < \delta < 1$ and if $\delta' > 0$, the rate of growth of population will be reduced by environmental deterioration below that which it would have been in the absence of such "Malthusian" effects; in particular, if η_Z starts out positive, it may eventually become negative as adult deaths increase.

Another reason to suppose that if η_Z begins positive it must eventually turn negative involves a factor which has not been explicitly introduced into the model. This is an absolute limitation on the number of births an individual woman can have in her lifetime. Such an absolute limitation implies that as environment deteriorates and the number of derived births increases, the elasticity of births with respect to the survival rate must be approaching 0 from below. Thus, if σ starts out less than -1, it will eventually become greater than -1; that is, if the rate of rise of optimal births is sufficiently rapid initially to make $\sigma < -1$, this rate must slow as the maximum number of births per woman is approached so that eventually σ must become less than one in absolute value.

What are the effects of *ex ante* child-bearing costs? We must distinguish between movements along the curve relating such costs to the number of births and shifts in the entire curve resulting from factors such as environmental deterioration which also affect child survival probability. Holding the *ex ante* cost curve fixed, we can easily see that the effects of decreasing survival in increasing the optimal number of births are partially offset if the marginal cost of additional births is positive. Thus, for any given utility function, the optimal number of births will be lower and will increase at a lesser rate as survival probabilities fall. We cannot say whether σ will increase or decrease in absolute value. If the marginal *ex ante* costs of an additional birth are constant, only the optimal number of births will be reduced; the effect of a fall in survival probability should be unchanged. Thus, σ may be higher in absolute value (more negative) for any given level of survival probability.

Suppose now that the entire *ex ante* cost curve shifts upward, marginal costs unchanged, as survival probabilities fall. Whatever the optimal response of birthrates in the absence of such shifts, it will be less when they occur; that is, the elasticity of births with respect to survival probability will be reduced in absolute value. Thus, *ex ante* costs of births, the level of which increases with environmental deterioration, makes it more likely rather than less that $\eta_Z < 0$ rather than $\eta_Z > 0$. But, of course, environmental deterioration may also change the slope of the *ex ante* cost curve and thus alter the elasticity η_Z in other ways.

To reach more definitive conclusions, it is necessary to specify more exactly the utility function of parents and the nature of the costs incurred in having children. I assume that all children born survive and *ex ante* costs are absent, and turn to the parable of firewood.

Endogenous Fertility 2: A Parable of Firewood

Suppose that all children survive birth and in the first period of life support their parents by gathering firewood which is shared out equally among family members. Any other sharing rule would do equally well. (There are no other *ex post* or *ex ante* costs of having an additional child other than the requirement that family production be shared.) Because all children survive, $b_t = n_t$.

Environmental deterioration is, as previously assumed, related to the size of the parents' generation, i.e., to the number of children working in the previous period. The larger this cohort, the greater the rate of environmental deterioration is assumed to be. Below a certain population, environment is assumed to be improving. The existing state of the environment is assumed to affect parents' perceptions of the benefit of having an additional child by affecting their expectations of the marginal productivity of an additional family member in gathering firewood and their perceptions of the level of the family production function. These expectations are formed at the time each parent decides how many children to have. While such decisions are assumed to reflect a correct perception of the relation between the size of her cohort and the future state of the environment, I do not assume that they take into account the possible behavior of other mothers or the effects of the number of children born on future states of the environment. Indeed, because parents are assumed not to care about their children's welfare, this behavior is consistent because the effects of the size of the children's cohort will be realized only after the parents are dead. Each mother decides how many children to have on the basis of her perception of the relationship between family income, the number of children she has,

and the state of the environment. This relationship embodies her beliefs about the productivity of her children and a correct assessment of the state of the environment during the period $t - 1$.

Note that the "production function" in this model is purely a family affair, but it could be, and likely is, related to some economy-wide production function having objective reality. Such a relationship is required if we are to interpret the function empirically. A "Nash-equilibrium" argument should suffice to establish the connection between such an economy-wide production function and the perceptions of individual parents.

In this context, it is assumed that the perceived marginal product of an additional child is positive but diminishing. Increased environmental deterioration reduces the family's harvest, *ceteris paribus,* but its effect on the perceived marginal product of an additional child may be either positive or negative.

Let x_t be the family's expected harvest, then

$$(4.1)\quad x_t = f(b_{t-1}, Z_{t-1}), \quad f(0, Z_{t-1}) = 0,$$

and where $f \geq 0$, $f_1 > 0$, $f_{11} < 0$, and $f_2 < 0$, for all $b \geq 0$ and $Z > 0$.

If the state of environmental degradation, Z, could be assumed to behave like the inverse of an ordinary factor of production, it would be plausible to argue that

$$f_{12} < 0,$$

so that increases in environmental quality would be expected to increase the marginal productivity of the other factor, namely, children. Similarly, the marginal effect of further environmental deterioration might be expected to diminish at greater levels of poorer quality environment, i.e., the better environmental quality, the greater the marginal effect of deterioration:

$$f_{22} < 0.$$

On the other hand, an argument can be made for opposite signs: For example, as forests recede up the mountain sides, parents may perceive a greater benefit of having an additional child to gather firewood. More realistically, in a poor agricultural setting, lower quality environments may be associated with a greater livestock component in total production, whereas higher quality environments may be associated with a greater crop component. Arguably, children have a comparative advantage over adults in tending livestock in contrast to the heavier labor of planting, tilling, and harvesting crops. Thus, environmental deterioration may well enhance the marginal productivity of children, at least relative to total family productivity. Similarly, environmental deterioration may accelerate the perceived adverse effects on family income: In very poor quality environments the effects of a given change in the quality of the environment may be larger than when the environment is in good shape.

Parents are assumed to choose the number of their offspring so as to maximize their own selfishly determined utility in the retirement period. Utility is assumed to be a monotone-increasing function of the parent's own consumption of firewood and nothing else. Thus, the parent maximizes

$$\frac{x_t}{b_{t-1} + 1} = \frac{f(b_{t-1}, Z_{t-1})}{b_{t-1} + 1}$$

with respect to b_{t-1}, taking Z_{t-1} as given. We drop temporal subscripts in what follows.

The first-order condition for a maximum of the per capita income in the family is

$$(4.2)\quad \frac{(b + 1)f_1(b, Z) - f(b, Z)}{(b + 1)^2} = 0, \text{ or}$$

$$b = \frac{f(b, Z)}{f_1(b, Z)} - 1, \text{ or}$$

$$f_1 = f/(b + 1).$$

Because $b = 0$ implies $f(0, Z) = 0$, $b = 0$ cannot be a solution to (4.2) as long as f_1 is strictly positive, even at $b = 0$. For $b > 0$,

$$\frac{\partial f/f_1}{\partial b} = \frac{f_1^2 - ff_{11}}{f_1^2} = 1 - \frac{ff_{11}}{f_1^2} > 1,$$

as a consequence of the diminishing marginal product of children and $f(b, Z) > 0$ for $b > 0$. Provided also f/f_1 is convex, the curve f/f_1 must cross the line $b + 1$ at some value $\bar{b}$ and thus (4.2) determines a unique value of the birthrate which is always positive, but which may be greater than, equal to, or less than 1 according to whether $f/f_1 \gtreqless 2$ at $b = 1$ (see fig. 1). And, thus, (4.2) defines a function h which relates each state of the environment Z_{t-1} to a unique positive value of the birthrate at the end of period $t - 1$:

$$(4.3)\quad b_{t-1} = h(Z_{t-1}) > 0.$$

It can happen, however, even in this case that

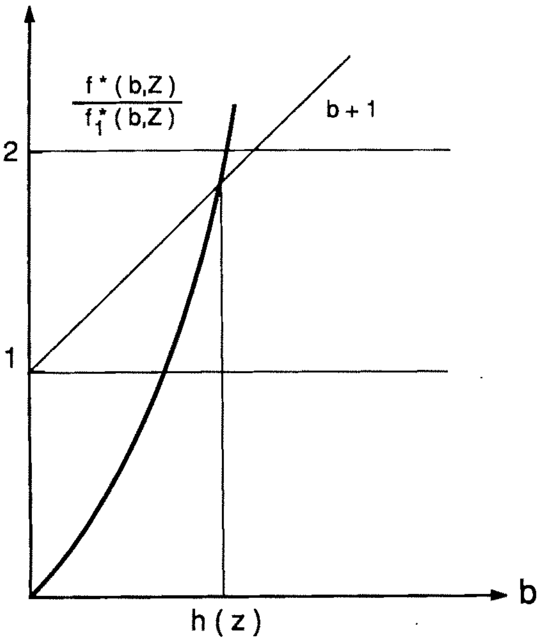


Figure 1. Determination of optimal birthrate

no solution to the equation $h(Z) = 1$ exists. Clearly, if

$$h(Z) > 1, \text{ or}$$
$$h(Z) < 1,$$

for all Z, no solution exists; $h(Z) > 1$ for all Z can occur if

$$f(1, Z) < 2f_1(1, Z) \tag{4.4}$$

for all Z. Similarly, $h(Z) < 1$ for all Z if for all Z,

$$f(1, Z) > 2f_1(1, Z). \tag{4.5}$$

To guarantee a solution to $h(Z) = 1$ if $h(Z)$ is continuous, it is sufficient that (4.4) holds for some values of Z and (4.5) for other values.

Before we examine the further properties of h, note that the second-order condition for a maximum is always satisfied because $f_{11} < 0$:

$$\frac{\partial^2[f(b, Z)/(b+1)]}{\partial b^2} = \frac{(b+1)^2 \frac{\partial}{\partial b}[(b+1)f_1 - f] - 2[(b+1)f_1 - f](b+1)}{(b+1)^4}$$
$$= \frac{(b+1)f_{11}}{(b+1)^2} = \frac{f_{11}}{b+1} < 0, \quad \text{for} \quad b > 0,$$

making use of the first-order condition.

How are the properties of the function $h(\ )$ in (4.3) related to those of $f(\ )$, which is the basis for parents' decision making with respect to fertility? First, let us determine h'. From (4.2),

$$h' = \frac{db}{dZ} = \frac{d}{dZ}\left[\frac{f}{f_1}\right] = \frac{\partial}{\partial b}\left[\frac{f}{f_1}\right]\frac{db}{dZ} + \frac{\partial}{\partial Z}\left[\frac{f}{f_1}\right],$$

so that

$$h' = \frac{\frac{\partial}{\partial Z}\left[\frac{f}{f_1}\right]}{1 - \frac{\partial}{\partial b}\left[\frac{f}{f_1}\right]}.$$

Now,

$$\frac{\partial[f/f_1]}{\partial Z} = \frac{f_1 f_2 - f f_{12}}{f_1^2} \quad \text{and}$$
$$\frac{\partial[f/f_1]}{\partial b} = \frac{f_1^2 - f f_{11}}{f_1^2} = 1 - \frac{f f_{11}}{f_1^2}.$$

Thus,

$$h' = \frac{f_1 f_2 - f f_{12}}{f f_{11}}. \tag{4.6}$$

Because $f_{11} < 0$ and $f > 0$, $b > 0$, the sign of h' is determined by

$$\operatorname{sign} h' = -\operatorname{sign}(f_1 f_2 - f f_{12}), \tag{4.7}$$

and because $f_1 > 0$, and $f_2 < 0$, and $f > 0$, for $b > 0$, we can say unambiguously

$$h' > 0, \quad \text{if} \quad f_{12} > 0, \tag{4.8}$$

that is, if the perceived marginal product of an additional child increases as environment deteriorates, birthrates increase as the environment worsens. In this case, good environmental quality is not like an ordinary factor of production. However, a more general interaction of environment and the marginal product of a child is possible because environmental quality may, at some levels, be like an ordinary factor of production, but in any case is not under the control of the decision-making parent.

From (4.6), we find after some manipulation that

$$h' = \frac{f_1 f_2}{f f_{11}} [1 - \varphi/\psi], \tag{4.9}$$

where

$$\varphi = f_{12} \frac{Z}{f_1}$$

is the elasticity of the marginal product of a child with respect to environmental deterioration and

$$\psi = f_2 \frac{Z}{f}$$

is the elasticity of family output with respect to environmental deterioration. We assume $f_1 > 0$, $f_2 < 0$, $f > 0$ and $f_{11} < 0$ for all $b > 0$ and, hence, for all Z. Thus,

$$h' \gtreqless 0 \text{ according as } 1 \gtreqless \frac{\varphi}{\psi}. \tag{4.10}$$

Because $f_2 < 0$, then $\psi < 0$. As we saw, $f_{12} > 0$ implies $h' > 0$ and also $\varphi > 0$ but $f_{12} < 0$ implies $\varphi < 0$. So, only when $f_{12} < 0$, that is, when environmental deterioration reduces the perceived marginal benefit of having an additional child, is the possibility open that such deterioration reduces the birthrate. But, even in this case, the effect is not unambiguous because, by (4.10),

$$h' \gtreqless 0 \text{ according as } |\psi| \gtreqless |\varphi|; \tag{4.11}$$

that is, if the elasticity of family income is greater in absolute value than the elasticity of the marginal product of a child, $h' > 0$, whereas, if the opposite is true, $h' < 0$. Moreover, these elasticities may change as environment deteriorates, which opens up the possibility that h' changes sign.

Suppose that Z is not like an ordinary factor of production when environmental quality is relatively good, that is $f_{12} > 0$, then environmental deterioration enhances the marginal productivity of a child so that at this level of Z, $h' > 0$. Now, however, suppose that as environment deteriorates it becomes more and more like an ordinary factor of production and further deterioration reduces the marginal productivity of a child as well as total family product. A possible explanation for the change in the nature of environment as a factor of production lies outside the narrow confines of the model; casual observation suggests that, under severe environmental circumstances, children actually become a drag on their parents' chances for survival. In any case, even if h' remains positive, rising adult death rates would ultimately lead to a fall in the rate of population growth.

Taxes, Subsidies, and Social Intervention

In the preceding two sections I have argued that multiple, at least two, stationary solutions to the dynamic system relating population and environmental quality are likely. The first of these, if there are two, is likely to be characterized by a positive response of fertility and the rate of growth of population to environmental deterioration and the second by a negative response. Only when there is such a negative response is there any possibility of obtaining a stable stationary solution under other plausible assumptions about the parameters of the system. This section considers how social intervention through a system of per capita taxes on children and lump-sum subsidies to parents can achieve any socially desired birthrate. Provided environment can eventually recover from the effects of excessive population growth, such a system of taxes and subsidies could be used to achieve and maintain any specified birthrate. In particular, social intervention could induce parents to determine their fertility in order, first, to reach a stationary solution—for example, the one with the lower level of population and better environment—and then to maintain that equilibrium despite its local instability. Clearly, those alive in all generations at the environmentally better equilibrium are better off than all who live at the environmentally worse equilibrium. But that does not mean that individual parents are better off; indeed, if, in the absence of taxes and subsidies, they would choose different levels of fertility, they are clearly worse off than if left to exercise their unfettered preferences. The welfare economics of environmental/population interactions is left to the next section, however, where parental altruism toward their children, or love, is discussed.

Reformulate the parent's optimization problem of the preceding section as follows: If the parent has b children, the family can gather $x = f(b, Z)$ units of firewood. However, firewood must be shared among family members, so each child "costs" the parent $p_b = x/(b + 1)$. The parent gets what is left over, y. So the parent's problem is

$$\max_b y \quad \text{subject to} \quad p_b b + y = x. \tag{5.1}$$

Now it is easy to see what the effect is of a tax, τ, per birth coupled with a lump-sum subsidy, σ; per parent, which need not be shared with her children. The budget constraint in (5.1) is now

$$(5.2) \qquad (p_b + \tau)b + y = x + \sigma,$$

where p_b is $x/(b + 1)$, as before. The parent takes τ and σ as given. Differentiating the expression

$$y = x - (p_b + \tau)b + \sigma$$

with respect to b yields the appropriate first-order condition:

$$(5.3) \qquad \begin{aligned} &\frac{\partial x}{\partial b} - (p_b + \tau) - b\frac{\partial p_b}{\partial b} \\ &= f_1 - f/(b + 1) - \tau \\ &- b\{(b + 1)f_1 - f\}/(b + 1)^2 \\ &= f_1/(b + 1) - \tau - f/(b + 1)^2 \\ &= 0. \end{aligned}$$

All taxes are returned to parents as a subsidy σ, so the subsidy per parent must equal $b\tau$. It follows that τ and σ are determined for any given $b = b^*$ as

$$(5.4) \qquad \begin{aligned} \tau^* &= \frac{f_1(b^*, Z)(b^* + 1) - f(b^*, Z)}{(b^* + 1)^2} \\ \sigma^* &= \tau^* b^*. \end{aligned}$$

τ^* and σ^* thus induce the parents to choose to have b^* children per family.

It is instructive to compare this solution with the result of unfettered parental preferences derived in the preceding section. There, the result was

$$b = f/f_1 - 1.$$

After some manipulation, we find

$$(5.5) \qquad b^* = f/(f_1 - [\tau^* + \sigma^*]) - 1;$$

so the tax/subsidy pair (τ^*, σ^*) works by reducing (augmenting if we allow τ^* and σ^* to be negative, i.e., to be a subsidy per child and a lump-sum tax per parent) the perceived benefit, f_1, of having an additional child.

Given a sequence of environmental qualities $Z_{-1}, Z_0, Z_1, \ldots$, the social planner can chose a sequence $(\tau_0^*, \sigma_0^*), \ldots$ to solve (5.5) for the sequence $b_0^*, b_1^*, \ldots$. In general, the planner can force the system to a particular stationary point of the system from any initial point away from that stationary point under general conditions, for example, provided that the sequence $\{b_t^*\}$ necessary to achieve this result were bounded away from zero, and population itself never became zero.

Parental Altruism: Love Is Not Enough

I now take up the difficult welfare issues which arise when there is parental altruism in the sense that parents love and value their children and their children's welfare over and above what their children may do for them. As remarked above, if parents do not care about their children's welfare and if all die at the end of the second period in our OLG model, they cannot be concerned about the consequence of their actions on future environmental quality because they are no longer alive to experience such effects when they occur. If, however, parents also love their children, matters are different. In this section, I argue that such love, in the absence of any goods other than firewood or children from which to obtain utility, can only increase parents' fertility over and above what they would choose in the absence of such altruism. Now, however, it becomes clear that unfettered parental choice may not lead to a Pareto optimum in which no parent can be made better off without making some others worse off, because the environmental resource which contributes to children's welfare is unpriced. Preferences are assumed stationary across generations; that is, parents and children have identical utility functions which are known to parents who can make interpersonal comparisons of utility—or, at least, believe they can. A consistent system of what are called "normally benevolent" utility functions (see Bergstrom) are the additively separable preferences

$$(6.1) \qquad U_t = u(c_t) + aU_{t+1}, \quad 0 < a < 1,$$

where U_t is the utility of the *i*th generation (see also Barro, and Razin and Ben-Zion). It is well known that this system of interdependent utility functions induces independent utility functions for each generation t which take the form

$$(6.2) \qquad U_t = u(c_t) + \sum_{j>t} a^{j-t}u(c_j).$$

In the present context, it is plausible that a parent derives utility from each of her children in proportion to their maximized utility. Thus, (6.1) may be rewritten as

$$(6.3) \qquad V_t = \max_{b_{t-1}} \{u(c_t) + ab_{t-1}V_{t+1}\}.$$

Some conditions, such as boundedness of the sequence $\{(ab_{j-2})^{j-t}, j = t + 1, \ldots\}$, must be imposed to ensure the existence of V_t defined in this way. The consumption of a parent of generation t is given in section 5: $c_t = f(b_{t-1}, Z_{t-1})/(b_{t-1} + 1)$, and the utility-maximizing birthrate in the absence of altruism is illustrated in figure 2. Suppressing time subscripts, setting u equal to its argument and replacing c_t in (6.3) by its value, we obtain the specific parent's problem in our context:

$$V_t = \max_b \{f(b, Z)/(b + 1) + abV_{t+1}\}.$$

Now V_{t+1} is clearly a function of what parents of this generation believe the future course of environment will be. In general, these beliefs will be erroneous. Each birth a parent chooses to have will diminish environmental quality in the future and thus the welfare of future generations. The parent cannot be expected to take this into account in making her individual decision, because her action alone has a negligible effect on future environmental quality. Using the system (2.1) and (2.4) to calculate the trajectories of N and Z, and the utility function of a parent (6.4), which a social planner would know only if he could calculate V_{t+1} for each generation, he then could, in principle, calculate an optimal sequence of birthrates so as to maximize the utility of a parent in the present generation. Such a calculation would take into account the true marginal cost of an additional birth in terms of its effects, through environmental deterioration, on the welfare of the next, and through them, subsequent generations. The difficulty for the planner is in knowing the beliefs of parents in the present generation. In effect, to solve the problem, the planner needs to know both what V_{t+1} is and what it ought to be, given a correct forecast of the future trajectory of environmental quality.

The problem of parents' beliefs could be resolved by introducing a model of expectations formulation, for example, static expectations in which parents assume the present state of environment will continue forever. This, however, hardly seems plausible except when the system is at a stationary point. At stationary points, we can indeed compute the difference in welfare, and the planner can, as suggested in the preceding section, choose a sequence of tax/sub-

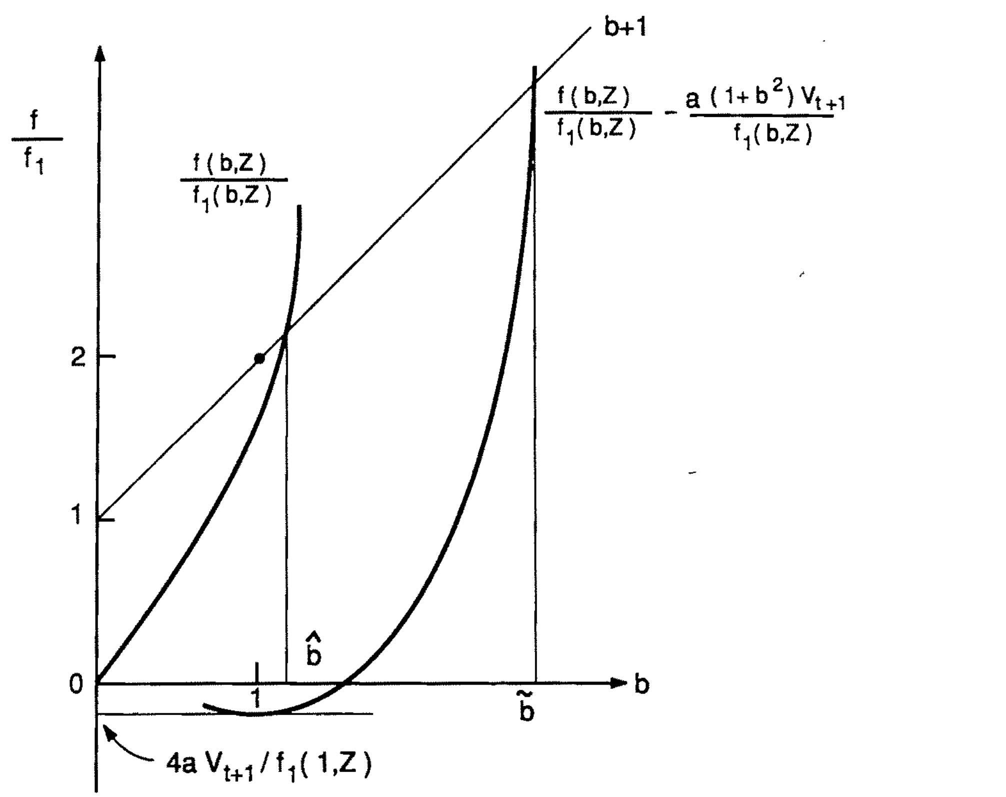


Figure 2. Effects of parental altruism on optimal birthrate

sidies to achieve and maintain the stationary state with the highest per capita utility for members of each generation. The only difference between these tax/subsidies and those of the preceding analysis is that birthrates will always be higher, for any given level of environmental quality, with parental altruism than without. Thus, per child taxes must be higher at a stationary point to maintain the system there with love than without.

To show the optimal level of births must be higher with altruism than without, compare the first-order conditions (4.2) with those obtained in the maximization problem (6.4), holding V_{t+1} fixed for the current generation:

$$(6.5)\quad \frac{(\tilde{b}+1)f_1(\tilde{b}, Z) - f(\tilde{b}, Z)}{(\tilde{b}+1)^2} + aV_{t+1} = 0,$$

where $\tilde{b}$ is the maximizing value for given Z and fixed V_{t+1}. Thus,

$$(6.6)\quad \tilde{b} = \frac{f(\tilde{b}, Z)}{f_1(\tilde{b}, Z)} - \left\{1 + \frac{a(\tilde{b}+1)^2 V_{t+1}}{f_1(\tilde{b}, Z)}\right\}.$$

Thus, the effect is to lower the curve $f(b, Z)/f_1(b, Z)$ in figure 2 everywhere by an amount which depends on a and V_{t+1} and a factor increasing in b. From figure 2, it is apparent that

$$(6.7)\quad \tilde{b} \geq \hat{b},$$

where $\hat{b}$ is the solution to

$$\hat{b} = \frac{f(\hat{b}, Z)}{f_1(\hat{b}, Z)} - 1.$$

When there is parental altruism, the tax rate necessary to achieve any given birthrate $b = \beta$ is higher by the altruistic effect per child, aV_{t+1}. To see this, observe that with tax/subsidy (τ, σ) and altruism, the parent's problem is

$$(6.8)\quad \max_b\{[f(b, Z) + \sigma] - [f(b, Z)/(b+1) + \tau - aV_{t+1}]b\}$$

for fixed σ, τ, and V_{t+1}. The first-order conditions follow from those derived previously, (5.3), by substituting $\tau - aV_{t+1}$ for τ. Thus, in contrast to τ^* in (5.4), we have

$$(6.9)\quad \tilde{\tau} = \frac{f_1(\beta, Z)(\beta+1) - f(\beta, Z)}{(\beta+1)^2} + aV_{t+1}.$$

An additional tax is necessary to offset the effects of love. Love is not only not enough to stabilize the relation between population and environment, it makes matters worse!

Conclusions

The dynamics of population/environmental interaction were developed in the context of a two-equation model in which the size of population is related to the past value of population and the value of environmental quality, and the level of environmental quality is related to its past value and to the past value of population. For a model of endogenous fertility, in which parents choose the number of births they have to maximize their utility and in which environmental degradation, Z, would converge for a fixed population and responds unfavorably to rising population, the relevant range of elasticities is

(7.1)

$0 < \xi_Z < 1$: Elasticity of environmental quality with respect to its past value.

$0 < \xi_N$: Elasticity of environmental quality with respect to population.

$\eta_N = 1$: Elasticity of population size with with respect to its past value.

The response of population size to environmental quality may be positive or negative, η_Z indeterminate. In a series of metaphors, I argued that η_Z might well start out positive but would, given sufficient environmental deterioration, ultimately become negative. Local stability is impossible with $\eta_Z > 0$, but limited possibilities for stability exist when $\eta_Z < 0$.

The effects of taxes on children and lump-sum subsidies to parents were next investigated. It was shown that it is generally possible to achieve a given birthrate with an appropriate tax/subsidy. Without parental altruism, such a policy is welfare reducing for the present generation. When parents are altruistic, the welfare-enhancing properties of taxes designed to achieve and maintain an equilibrium with good environment and low population are problematic.

This leads to a final point: The model relates only population and environment. There is no possibility for investment in physical capital to improve or maintain environmental quality or for investment in human capital to improve the quality of children's lives and enhance the utility parents derive from having children without increasing their numbers. The bulk of recent work on growth and endogenous fertility revolves around these two types of capital formation. There is no doubt in my mind that introduction of physical capital formation to offset the environmentally adverse effects of population pressure and of human capital formation to en-

hance the quality of individual children would result in far more optimistic conclusions. The mathematics of introducing such possibilities, however, is more complicated than the analysis of dynamic planar system on which the analysis of this paper is based. Much remains to be done, but the present work offers a beginning to the study of the difficult issues of intergenerational welfare economics which must be confronted in any attempt to understand and cope with problems of population/environmental interaction.

References

Barro, R. J. "Are Government Bonds Net Wealth?" *J. Polit. Econ.* 82(1974):1095–1117.

Bergstrom, T. "Systems of Benevolent Utility Interdependence." Unpublished, 1990.

Freedman, R. *The Sociology of Human Fertility*. New York: Irvington, 1975.

Grantmont, J. M. "On Endogenous Competitive Business Cycles." *Econometrica* 53(1985):995–1045.

Guckenheimer, J., and P. Homes. *Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields*. New York: Springer-Verlag, 1986.

Hardin, G. "The Tragedy of the Commons." *Science* 162(1968):1243–48.

Iooss, J., and D. D. Joseph. *Elementary Stability and Bifurcation Theory*. New York: Springer-Verlag, 1990.

Jodha, N. S. "Rural Common Property Resources: Contributions and Crisis." Foundation Day Lecture, May 1990, Society for the Promotion of Wastelands Development.

McNicholl, G. "Social Organization and Ecological Stability Under Demographic Stress." The Population Council work. pap. no. 11, 1990.

Neher, P. A. "Peasants, Procreation, and Pensions." *Amer. Econ. Rev.* 61(1971):380–89.

Nerlove, M. "Household and Economy: Toward a New Theory of Population and Economic Growth." *J. Polit. Econ.* 82(1974):S200–218.

Nerlove, M., and A. Meyer. "Population and the Environment: Some Dynamics." Paper presented at a Conference on Nonlinear Dynamics and Econometrics, University of California, Los Angeles, April 1991.

Nerlove, M., and A. Meyer (with V. Dalkó). "Endogenous Fertility and the Environment: A Parable of Firewood." Paper presented at a UN University/WIDER Conference on Economic Development and the Environment, Helsinki, Finland, Sep. 1990.

Nerlove, M., A. Razin, and E. Sadka. *Household and Economy: Welfare Economics of Endogenous Fertility*. New York: Academic Press, 1987a.

——. *Population Policy and Individual Choice: A Theoretical Investigation*. Washington DC: International Food Policy Research Institute Res. Rep. No. 60, 1987b.

Preston, S. H. *Mortality Patterns in National Populations*. New York: Academic Press, 1976.

Preston, S. H., ed. *The Effects of Infant and Child Mortality on Fertility*. New York: Academic Press, 1978.

Razin, A., and U. Ben-Zion. "An Intergenerational Model of Population Growth." *Amer. Econ. Rev.* 65(1975):923–33.

Sah, R. K. "The Effects of Child Mortality Changes on Fertility Choice and Parental Welfare." *J. Polit. Econ.* 99(1991):582–606.

Schultz, T. P. *Economics of Population*. Reading MA: Addison-Wesley Publishing Co., 1981.

Schultz, T. W. *Economics of the Family: Marriage, Children and Human Capital*. Chicago: University of Chicago Press for the National Bureau of Economic Research, 1974.

Simon, J. L. *The Economics of Population Growth*. Princeton NJ: Princeton University Press, 1977.

Willis, R. J. "The Old-Age Security Hypothesis and Population Growth." *Demographic Behavior: Interdisciplinary Perspectives on Decision Making*, ed. T. K. Burch. Boulder CO: Westview Press, 1980.

Wolpin, K. I. "An Estimable Dynamic Stochastic Model of Fertility and Child Mortality." *J. Polit. Econ.* 92(1984):852–74.

Invited Papers Sessions

Improving Macroeconomic Policy Considerations in Agricultural Research and Education
(Kirby Moulton, University of California, Berkeley, presiding)

Macroeconomic Policy and Agricultural Economics Research

David Orden and Lance A. Fisher

In this paper we have the task of discussing some of the implications for agricultural economics research of linkages from macroeconomic policy to the agricultural sector. Even a few years ago, we might have felt compelled by this task to review a wide range of studies in order to give a fair hearing to some of the controversies in this area. Recently, however, the association has provided ample opportunities for discussion of these issues. In addition, many of the good technical papers have also found an outlet in the *AJAE*. Reviewing this accumulated body of literature would be a daunting task and, given other such efforts, one with a questionable marginal payoff.[1]

Consequently, we would like to approach our assignment about macroeconomic policy and agricultural economics research from a different perspective. We will proceed by reviewing recent developments in the trade-dependent Australian economy, with particular attention to the management of macroeconomic policy and the effects of the financial sector reforms undertaken in the 1980s. The third section of our paper discusses the cointegration literature—the recent developments in time-series analysis that provide a methodology for distinguishing between the long-run equilibrium relationships of an economy and the process of short-run dynamic adjustment. In the fourth section, these techniques are applied to small models of the Australian economy, modeling first the net import position and, in turn, interactions of selected macroeconomic aggregates with sectorally disaggregated export values. Our discussion comes about half way through a research endeavor in this area, and we conclude with a few general remarks about the challenges facing this and other research on macroeconomic linkages to agriculture.

Background on the Australian Economy

Australia is a small, trade-dependent, Pacific economy that historically has been one of the wealthiest countries of the OECD. Over the last twenty-five years, its relative income standing has slipped and it has experienced relatively high rates of inflation. Australia remains dependent on raw material and agricultural exports. Its industrial sectors are generally small, oligopolistic, and protected from world competition. The resulting pattern of exports and imports has led to a close relationship between Australia's external terms of trade and its real exchange rate (see Clements and Freebairn). In principle, these are distinct concepts, with the former measuring the relative prices of exports to imports and the latter measuring the relative price of nontraded goods to all traded goods. In Australia, these two relative price measures have moved closely together as changes in the terms of trade have affected income and, hence, demand in the domestic economy.

Until the 1980s, the financial sector in Australia remained tightly regulated and the nominal exchange rate was fixed, with significant implications for macroeconomic policy management. A government inquiry in 1979 endorsed

---

David Orden is an associate professor, Department of Agricultural Economics, Virginia Polytechnic Institute and State University; Lance A. Fisher is a lecturer, School of Economics, University of New South Wales, and is currently on leave at VPI&SU.

The authors thank the Australian Research Council for financial support.

[1] For recent surveys see Belongia or Kitchen and Orden. For recent dissertations on macroeconomic impacts on agriculture see Tyler Bowles (UNC-Chapel Hill), Young Chan Choe (Michigan State University), David Gillette (Washington State University), and Francis In (Cornell).

financial deregulation and resulted in the lifting of some interest rate controls in 1980. The Reserve Bank also began announcing a target range for M3. The bank apparently had a view toward using these targets to control inflation but retained the claim that the announced range was a general forecast not a specific policy target.

Implementation of reform in the Australian financial sector was accelerated after election of the Labor government of Bob Hawke in March 1983. A second inquiry supported financial liberalization as consistent with the principles of the Labor Party. Exchange controls were lifted and the dollar floated in late 1983, with further removal of domestic interest rate ceilings in 1984–85. These reforms, together with full competitive funding of government deficits, were viewed as preconditions for control of the reserve base, and hence, some argued, inflation, by the monetary authorities. Deregulation, including limited entry of foreign banks, was also designed to increase the competitiveness and efficiency of the financial sector.

As elsewhere, a policy issue that has arisen in the context of Australian financial deregulation has concerned the intermediate targets of monetary policy. An option was to target one of the various monetary aggregates. However, while deregulation enhanced the monetary authority's control of reserves, it also affected demands for monetary assets. Together with other financial innovations, this resulted in a breakdown of well-behaved relationships among the monetary aggregates and nominal GDP or inflation, at least in the short run. In particular, M3 expanded rapidly with the reintermediation process that followed the lifting of interest rate controls. This resulted in the Reserve Bank abandoning announced M3 targets in January 1985.

Further, control of inflation has not been the sole priority of monetary policy in Australia (Sieper and Wells). Rather, the Hawke government appeared to rest its anti-inflation strategy on agreements with organized labor known as the Accord. Lower rates of wage increases were traded for lower rates of taxation, with the maintenance of reasonable rates of inflation being an anticipated outcome. Meanwhile, the focus of monetary policy was placed initially on maintaining the momentum of economic growth (Milbourne).

Starting in 1986, the current account balance in Australia began to deteriorate. One response was to shift toward fiscal surplus by cutting the level of government expenditures (the Accord ruled out tax increases). The shift in fiscal stance has not achieved noticeable improvement in the current account, but it has allowed the treasurer to assert that the foreign debt being incurred is private debt not sovereign debt, an issue that has arisen in the political debate over whether Australia is sliding toward the status of a "banana republic."

Monetary policy has also been perceived as a tool for addressing the current account deficit. With the abandoning of monetary targeting, the Reserve Bank has pursued a "checklist" approach. Levels of the nominal exchange rate and interest rates, and the spread between short and long-term interest rates, have been prominent among their intermediate indicators. The recent strategy with respect to the current account has been to try to suppress domestic demand with high interest rates. This policy approach, which rests on arguing that Australia has a very high income elasticity of import demand, fits neither the overshooting model of Dornbusch nor the competing views about real determinants of the exchange rate of Stockman and others. (In the former, tight monetary policy deteriorates the current account in the short run; while in the latter, monetary policy has no real effects.) Critics have argued that this policy has led to too high a value of the Australian dollar (the Dornbusch effect), with the relative price effect on net imports offsetting the intended income effect (Bewley). Critics have also argued that pursuit of such short-term objectives has induced a domestic recession on the one hand, and, as opposed to monetary targeting, is inconsistent with longer-term stability of inflation expectations on the other hand (Stemp and Murphy). Inflation remained around 6%–7% through 1989 and the Reserve Bank began to emphasize the inflationary risks of a nominal depreciation. During the past year, the Australian economy has slipped into recession (unemployment at almost 10%) and interest rates have been lowered markedly. Politically, a recent bid for leadership of the government by the reform-oriented treasurer was defeated and he resigned from the cabinet.

Modeling Long-Run Relationships

To undertake modeling of some of the interactions in the Australian economy, we have drawn on the recent developments in time-series methods for estimating long-run responses, and the related short-run dynamics, in both single equations and systems of equations. For models of the aggregate economy, feedback effects among

the variables are certain to be important and a system model seems appropriate. Issues arise about statistical adequacy of the reduced-form specification, including addressing nonstationarity and cointegration, and about structural identification. Here, we focus on the former, in particular on modeling restrictions on the long-run relationships among the series in the presence of the nonstationarity that is characteristic of macroeconomic aggregates due to unit roots. Long-run "cointegrating" relationships among such series have a nice intuitive interpretation as stationary equilibrium to which the economy has a tendency to return, while the short-run dynamics subject to these restrictions characterize the adjustment process in response to the myriad of shocks that jolt the economy.

To focus on the nature of the problem, a VAR model is

$$Z = ZA(L) + XG + W, \tag{1}$$

where Z and W are $T \times p$ matrices of observations and i.i.d. normal disturbances, respectively; X is a $T \times k$ matrix of deterministic components; $A(L) = A_1L + \ldots + A_nL^n$, with A_i being $p \times p$ matrices of parameters; G is a $p \times k$ matrix of parameters; $E(W) = 0$ and $T^{-1}E(W'W) = \Omega$. Equation (1) can be reparameterized as

$$\Delta Z = Z_{-1}\Pi + \Delta ZA^*(L) + XG + W, \tag{2}$$

where $\Pi = [A(1) - I]$; and $A_i^* = -[A_{i+1} + \ldots + A_n]$ or, without loss of generality, as

$$\Delta\tilde{Z} = \tilde{Z}_{-1}\Pi + W, \tag{3}$$

where $\Delta\tilde{Z}$ and $\tilde{Z}_{-1}$ are matrices of residuals from regressions of ΔZ and Z_{-1} on X and the lagged ΔZ's.

Equation (3) focuses attention on the matrix Π, which provides information about the long-run relationships among the series. If Π is of full rank, there is a unique equilibrium solution $\tilde{Z} = 0$. However, when the series in $\tilde{Z}$ are integrated to order 1 and are cointegrated, $0 < \text{rank}(\Pi) < p$. It is only in the case of $I(1)$ variables and no cointegration that the first-difference model is appropriate; otherwise, inappropriate differencing removes long-run economic relationships and biases parameter estimates.

The least squares estimate of Π is inefficient in the presence of rank restrictions, and recently a number of alternatives have been proposed to impose them. Space limitations preclude a full discussion of these alternatives, but a maximum likelihood (ML) procedure developed by Johansen (1988) can be summarized as follows. First, solving the maximum likelihood problem for model (1) under the hypothesis of reduced rank for Π is equivalent to solving

$$[(\tilde{Z}_{-1}'\tilde{Z}_{-1})^{-1}\tilde{Z}_{-1}'\Delta\tilde{Z}(\Delta\tilde{Z}'\Delta\tilde{Z})^{-1} \Delta\tilde{Z}'\tilde{Z}_{-1}]M = M\Gamma \tag{4}$$

for the eigenvectors (columns of) M and the eigenvalues $\Gamma = \text{diag}\{\gamma_1 \ldots \gamma_p\}$. Notice that the expression being decomposed is simply $\hat{\Pi}\tilde{\Pi}$, where $\hat{\Pi}$ is the OLS estimator from equation (3) and $\tilde{\Pi} = (\Delta\tilde{Z}'\Delta\tilde{Z})^{-1}\Delta\tilde{Z}'\tilde{Z}_{-1}$ is the least squares estimate of the parameter matrix in the "reverse" regressions of $\tilde{Z}_{-1}$ on $\Delta\tilde{Z}$. From this expression, the eigenvalues are seen to be the R^2 for regressions of the transformed differences $\Delta\tilde{Z}M$ on transformed lagged levels $\tilde{Z}_{-1}M$, or the squared canonical correlations between differences of the initial series and their lagged levels (Johansen's theorem 1, see also Bewley and Orden). The columns of M are the canonical weights on the lagged levels. Columns corresponding to the largest eigenvalues are possible cointegrating relationships. Partitioned on this criterion, $M = [M_1 : M_2]$, where M_1 is the $p \times r$ matrix which forms the basis for Π. The intuition for this approach is that only stationary linear combinations of the (lagged) levels are correlated with the stationary differences, at least asymptotically, and should be included in equation (3).

Determining the number of columns of M_1 (or the rank of $\hat{\Pi}$ or number of nonzero eigenvalues) is equivalent to determining the number of independent unit roots in the model (1), say r and $p - r$, respectively. A likelihood ratio test statistic for the null hypothesis of no more than r stationary linear combinations of the series versus alternatives up to all series being stationary is

$$-T \sum_{i=r+1}^{p} \ln(1 - \hat{\gamma}_i). \tag{5}$$

The distributions of these trace test statistics are multivariate versions of the Dickey-Fuller distributions and depend on the number of unit roots under the null hypothesis. Critical values are tabulated in Johansen and Juselius and Osterwald-Lenum.

Models of the Australian Economy and Trade

Our initial work on modeling the Australian economy focused on the effects of financial lib-

eralization on the dynamic interactions among money (M3), the price level, output (GDP), and short-term interest rates (see Orden and Fisher). The results suggested nonstationary series with a single cointegrating relationship among money, prices, and output that breaks down under the financial deregulation. For the prederegulation period, the hypothesis that money and prices are proportional in the long run (i.e., that their coefficients in the cointegrating vector are equal but of opposite sign) received overwhelming support, while proportionality of money and output and, hence, stationarity of the velocity of money circulation per se, was rejected.[2] The full set of parameters of the VAR model were then used to evaluate the dynamic and long-run adjustments resulting from various shocks to the Australian economy, under a recursive structural identification.[3] One of the principal findings was that shocks to money had little effect on real output, with money and prices tending to move proportionately in the long run in response to monetary shocks.

To extend this analysis, we have recently been evaluating models of the Australian economy incorporating world income (*WI*), the real exchange rate (*RTWI*), and some measure of trade performance in addition to domestic money, prices, and output. These models allow tests of the robustness of the long-run neutrality results from the earlier model and can be used to address the dependence of the Australian economy on world income growth, the importance of trade sectors to the aggregate economy, and possible relative price and sectoral effects of monetary policy.

Some preliminary results about the long-run equilibrium relationships in the economy are reported for a model of Australia's net imports in table 1.[4] There is strong evidence of cointegration in this aggregate model through the period of financial deregulation. On the basis of the likelihood ratio tests, one might even argue that there are no unit roots in the model, but there is contradictory evidence because $r \leq 4$ is not rejected even on the basis of the 80% critical value.

Interpretation of multiple cointegrating vectors among jointly determined series is complicated because any linear combination of the cointegrating relationships is also a cointegrating relationship (see Johansen and Juselius for discussion). Alternatively, r-cointegrating vectors define equilibrium equations which can be normalized to express r series as functions of the remaining $p - r$ series. The coefficients in these equations are the long-run relationships of each of the first set of series to levels of each of the second set.

For our aggregate model of the Australian economy, it seems reasonable to assume there are five cointegrating vectors and evaluate long-run relationships in which the domestic series are expressed in terms of world income. The results are also shown in table 1, and they seem to give a plausible characterization of the Australian economy relative to the rest of the world. For a given 1% growth in real world income, Australian income rises 0.77%. Prices rise 2.40%, reflecting the historically greater levels of inflation in Australia, and money rises about proportionally to the sum of income and prices, reflecting a relatively stable velocity of money circulation. Net imports fall, as world income growth creates demand for Australian exports, and the real exchange rate depreciates slightly. In short, dependence on world income seems a reasonable way to model the stochastic trends in the Australian economy. The estimated relationships of money, prices, output, and net imports to world income are robust to expressing these four series as functions of world income and the real exchange rate under an assumption of two unit roots.

If net imports are replaced by real values of specific exports, relationships between these exports and the aggregate economy can be examined in separate models that share a common set of macroeconomic series. Results for eight dissagregated export sectors and total exports are shown in table 2. Real exports are measured by nominal values deflated by the overall GDP deflator, so changes in real values include both quantity and relative price effects. (See Bewley and Orden for related discussion of Australian import demand, income, and relative prices.)

[2] See Johansen and Juselius for discussion of tests of restrictions on the cointegrating vectors.

[3] With the number of cointegrating relationships determined and the (possibly restricted) cointegrating vectors estimated, substituting $\hat{M}_1$ into equation (2) yields the vector error-correction (VEC) model

$$(2') \qquad \Delta Z = (Z_{-1}\hat{M}_1)C + \Delta Z A^*(L) + XG + W,$$

where $Z_{-1}\hat{M}_1$ are the error-correction terms. Maximum likelihood estimates of the remaining parameters of (2′), and hence of the restricted equation (1), can be obtained by OLS.

[4] Sample period was 1970:Q1–1990:Q2. The series for money, prices, output, and net trade were seasonally adjusted by source. The real exhange rate is from ABARE (see J. Dwyer and P. O'Mara) and the world income measure is a trade-weighted index. The levels VAR was specified in logs with four lags of each variable (net trade is the ratio of imports to exports). The model also included a constant and a structural change shift parameter for the postliberalization period.

Table 1. Long-Run Properties of an Aggregate Model of the Australian Economy

Tests for Cointegration

Number of vectors	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$	$r \leq 5$
Trace statistic	152.02	100.14	53.26	27.56	11.69	5.11
90% critical value[1]	90.39	66.49	45.23	28.71	15.66	6.50
80% critical value[1]	85.38	61.75	41.65	25.39	13.21	4.82

Long-run relationships of domestic series to world income

$M3 = 3.35\ WI$
$\text{Prices} = 2.40\ WI$
$\text{GDP} = .77\ WI$
$\text{Net imports} = -1.07\ WI$
$RTWI = -0.06\ WI$

[1] Critical values are from Johansen and Juselius and Osterwald-Lenum.

The number of cointegrating vectors supported in the model for each export sector is reported in the second column of table 2 (the results are based on the 90% critical values for the likelihood ratio statistics). To determine whether the sectoral exports contribute to defining the long-run equilibrium of the economy, the restrictions that the coefficients of each export series are zero in these cointegrating vectors were tested. Probability values of the resulting test statistics are reported in the third column of table 2.

In the models for exports of minerals (plus ores and metals) and wool, there is evidence of four cointegrating vectors. These sectoral exports appear to be highly significant in determining the long-run equilibrium relationships for the aggregate economy. Wheat exports are also highly significant in the cointegrating vectors, with evidence for three stationary long-run relationships in the wheat model.

There is also evidence for three cointegrating vectors in the models for exports of meats and manufactured goods. Evidence that the coefficients on these sectoral exports are nonzero in the cointegrating vectors is weaker than for minerals, wool, and wheat.

For the models for sugar exports, other rural exports, and other nonrural exports, there is evidence for only two cointegrating vectors. The coefficients of these exports are not significantly different from zero in the cointegrating vectors at the 0.05 significance level.

Overall, these results suggest that Australia's key exports play a role in determining the long-run equilibrium of the economy at the aggregate level, while minor export commodities do not.

A second way to explore the linkages from the long-run equilibrium to various components of the economy is to evaluate whether deviations from the equilibrium relationships affect the dynamics of adjustment (i.e., test the significance of the relevant coefficients on the error-correction terms in the matrix C of foot-

Table 2. Cointegration in Disaggregated Export Models

			Tests of Zero Restrictions	
Commodity	% 1990 Exports	Number of Cointegrating Vectors	Exports in Cointegrating Vectors	Error-Correction Terms in Export Dynamics
Minerals, ores, metals	51.4	4	0.0005	0.002
Wool	6.2	4	0.0010	0.015
Wheat	5.8	3	0.0001	0.001
Manufactures	16.4	3	0.0100	0.339
Meats	6.2	3	0.0200	0.001
Sugar	2.0	2	0.1300	0.721
Other rural	8.8	2	0.4100	0.044
Other nonrural	3.2	2	0.0800	0.005
Total	100.0	4	0.0001	0.032

note 3). Among the macroeconomic aggregates, the results (not shown) unambiguously support the conclusion that the deviations from equilibrium play an important role in the dynamic adjustments of each series. This is an important result because it is exactly these effects that are assumed to be zero in models specified in differences.

Results of tests of restrictions that the joint effects of the deviations from economy-wide equilibrium on the adjustment dynamics for disaggregated exports are zero are shown in the final column of table 2. The short-run dynamic adjustments of minerals, wool, and wheat exports appear to be affected by these terms; results that are consistent with the significance of the export commodities in the cointegrating relationships. Among the remaining export sectors, the results are mixed. Deviations from equilibrium in the economy do not appear to be significant in the dynamics of manufacturing or sugar exports but are significant for meats and other rural and other nonrural exports.

Conclusions

In this paper we have reviewed recent developments in the trade-dependent Australian economy and focused attention, in terms of modeling strategies, on recent time-series methods for disentangling long-run equilibrium relationships from short-run dynamics. We report finding a stationary long-run relationship among money, prices, and output in Australia prior to the introduction of financial-sector reforms in the early 1980s, with money and prices proportional in the long run. We also find stationary equilibrium relationships among domestic macroeconomic aggregates and world income through the period of financial deregulation.

In other ways, it is less easy to interpret the events and policy issues in Australia using basic economic theory. One puzzle concerns monetary policy and the current account. When the current account deteriorated, policy makers in Australia opted to try to dampen income growth with high nominal interest rates. In the Dornbusch framework, this kind of tight monetary policy is likely to cause currency appreciation and further short-run current account deterioration. In fact, little change occurred in the Australian current account until very recently as the economy has fallen into a serious recession. Lower growth with a relatively highly valued dollar seems a less optimal path for the economy than more rapid growth and relative price adjustment (depreciation) to maintain current account balance. More work needs to be done to understand Australian policy choices and their outcomes.

A second area in which the Australian experience poses a puzzle is in the relationship between financial liberalization, monetary targets, and the exchange rate. One of the key arguments for reforms such as floating the currency, liberalizing capital markets, and full market funding of government deficits was to obtain control of the domestic money supply, and, hence, presumably domestic inflation. However, these reforms also created enough structural change in money demand to make monetary targets unattractive to policy managers, at least in the short run. Levels of nominal interest rates and the nominal exchange rate reemerged as targets of policy. But real factors, such as the external terms of trade, also play an important role in Australian exchange rate determination. More work needs to be done to understand how much scope this really leaves the monetary authorities in exchange rate management and on where the pressures will emerge if an attempt is made to maintain an unsustainable exchange rate level.

Our preliminary results from modeling the Australian economy in a world context provide insights into some of the real determinants of macroeconomic performance. The model of net imports is characterized by multiple stationary equilibrium relationships. Domestic macroeconomic aggregates show reasonable relationships to world income in the long run, and we recover a sensible relationship between money, prices, and output in this context. Thus, world income seems to be a plausible measure of the stochastic trends in the Australian economy.

Our models of disaggregated export sectors show that values of key Australian exports such as minerals, wool, and wheat also contribute to defining the economy's long-run equilibrium. In turn, dynamic adjustments in these sectors are significantly affected by deviations from the long-run relationships, as are the dynamic adjustments of the macroeconomic aggregates. More work needs to be done to disentangle these dynamics of the Australian economy. These are the types of challenges we face in agricultural economics in understanding macroeconomic policy and its effects on agriculture. Models of the kind we are developing will play a role in this analysis, as will others.

References

Belongia, M. T. "Monetary Policy and the Farm/Nonfarm Price Ratio: A Comparison of Effects in Alternative Models." St. Louis MO: Federal Reserve Bank of St. Louis, *Rev.*, no. 4 (1991), pp. 30–46.

Bewley, R. "Current Account Deficits Matter." Paper presented at the Conference of Economists, Sydney, Australia, Sep. 1990.

Bewley, R., and D. Orden. "Alternative Methods for Estimating Long-Run Responses with Application to Australian Import Demand." Paper presented at the Symposium on Cointegrated Systems, Australasian Meetings of the Econometric Society, Sydney, Australia, July 1991 (forthcoming in *Econometric Reviews*).

Clements, K., and J. Freebairn, eds. *Exchange Rates and Australian Commodity Exports*. Centre of Policy Studies, Monash University and Economic Research Centre, University of Western Australia, 1990.

Dornbusch, R. "Expectations and Exchange Rate Dynamics." *J. Polit. Economy* 84(1976):1161–75.

Dwyer, J., and P. O'Mara. "Measuring Australia's Competitiveness." *Quart. Rev. Rural Econ.* 10(1988):54–59.

Johansen, S. "Statistical Analysis of Cointegration Vectors." *J. Econ. Dynamics and Control* 12(1988):231–54.

Johansen, S., and K. Juselius. "Maximum Likelihood Estimation and Inference on Cointegration—with Applications to the Demand for Money." *Oxford Bull. Econ. and Statist.* 52(1990):169–210.

Kitchen, J., and D. Orden. "Effects of Fiscal Policy on Agriculture and the Rural Economy." Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Staff Rep. No. 9131, June 1991.

Milbourne, R. "Money and Finance in Australia: A Decade of Change." *The Australian Macroeconomy in the 1980s*, ed. S. Grenville. Sydney: Reserve Bank of Australia, 1990.

Orden, D., and L. A. Fisher. "Financial Deregulation and the Dynamics of Money, Prices and Output in New Zealand and Australia." School of Economics Disc. Pap. 90/9, University of New South Wales, Dec. 1990.

Osterwald-Lenum, M. "Recalculated and Extended Tables of the Asymptotic Distribution of Some Important Maximum Likelihood Cointegration Test Statistics." Mimeographed. Institute of Economics, University of Copenhagen, Jan. 1990.

Sieper, E., and G. M. Wells. "Macroeconomics on the Left: Australia and New Zealand in the Eighties." *Australian Economic Policy*, ed. F. Gruen. Canberra: Centre for Economic Policy Research, Australian National University, 1991.

Stemp, P. J., and C. W. Murphy. "Monetary Policy in Australia: The Conflict Between Short-term and Medium-term Objectives." Mimeographed. Canberra: Australian National University, 1990.

Stockman, A. C. "The Equilibrium Approach to Exchange Rates." Richmond VA: Federal Reserve Bank of Richmond *Econ. Rev.*, no. 2 (1988), pp. 12–30.

Analyzing Extension's Role in Macroeconomic Policy Education

William M. Snell and Craig L. Infanger

. . . monetary and fiscal policies, both here and abroad, have more influence on the markets of U.S. farmers and on the prices they receive than do the domestic conditions of agricultural demand and supply. —Schuh 1991

[The] agricultural economics profession has given very little emphasis to macropolicy principles, research and extension education. In my view, a big weakness in the profession and the *AJAE*. —1991 Survey of State Extension Specialists

During the past two decades, agricultural economists have heightened their awareness of the importance of macroeconomic policy changes on the agricultural sector (Schuh 1974, Orden 1988, McCalla 1982, Tweeten, Harris and Rosson, Kitchen and Monaco). A considerable amount of attention has been devoted in the research literature to analyzing the actual and potential impacts of various monetary and fiscal policy shocks on the agricultural economy (Orden 1986; Frankel; Penson and Gardner; Gardner; Bosworth and Lawrence; Chambers; Starleaf, Meyers, and Womack; Barnhart).

We pose a corollary question about extension education: "What is and what should be extension's role in macroeconomic policy education?"[1] Tweeten argues that macroeconomic policy deserves as much attention from farmers as commodity policy. However, it seems to us that extension public policy and commodity specialists have devoted considerably more attention over the years to policies that impact agriculture directly (e.g., the farm bill) than to the relationship of macropolicy and agriculture. If macroeconomic policies play a major role in influencing the agricultural economy, then we should expect to see agricultural economists conducting vigorous extension education programs on this topic. The decade of the 1980s provided an excellent *raison d'etre:* The restrictive monetary policy and expansionary fiscal policy during the early years of the Reagan administration escalated real interest rates, depressed agricultural trade, reduced asset values, and increased the debt burden for agriculture. Although much of the rebounding of the U.S. agricultural economy during the latter 1980s was credited by some to the 1985 farm bill, favorable macroeconomic conditions played a major role in improving the U.S. agricultural economy (McCalla 1990). Given expanding international trade and fiscal pressures to lower outlays for agricultural programs, domestic and foreign macroeconomic policies will likely play an even greater role in determining the fate of U.S. agriculture during the 1990s.

Based on the above observations, it appears vital that extension economists provide effective educational programs to educate farmers, agribusinesses, and policy makers on macroeconomic linkages to agriculture and rural communities. Knowledge about the relationship of various macropolicy changes on agriculture should enable agricultural businesses to be in a better position to react strategically to actual or anticipated changes in the macroeconomy. In addition, knowing the rudiments of the macroeconomic policy-making process should permit more farmers and agribusinesses to become more active players in policy formulation.

Unfortunately, extension economists face many challenges in delivering effective macroeconomic policy educational programs. The objective of this paper is to analyze extension's role in macroeconomic policy education by identifying the challenges, discussing existing educational programs, and providing some strategic recommendations to the profession on ways to improve macroeconomic policy education. The paper is divided into four sections. The first sec-

---

William M. Snell is an assistant extension professor, and Craig L. Infanger is an extension professor, Department of Agricultural Economics, University of Kentucky.

The authors wish to thank Larry Jones, Jerry Skees, and Barry Barnett for their comments on drafts of this paper.

[1] Macroeconomic policy in this paper is defined to include monetary, fiscal, and trade policy. For convenience we will refer to this as "macropolicy." Agricultural policy is considered separate from macroeconomic policy.

tion briefly identifies issues confronting extension education on macroeconomic policy and agriculture. Next, the paper presents the results of a survey conducted to obtain the attitudes of agricultural economics state extension specialists and department chairmen on macroeconomic policy issues and programming strategies. The third section reviews programming activities currently being utilized in Kentucky to develop a more informed and active agricultural base on macroeconomic policy and agriculture. Finally, the paper provides some strategic recommendations to the profession for improving macropolicy education.

Issues Confronting Extension on Macroeconomic Policy Education

Agricultural economists who want to incorporate effective macropolicy concerns into existing educational efforts or attempt to mount stand-alone educational programs on some macropolicy component (e.g., trade policy) face some major issues and concerns. At a most basic level lies our perception, understanding, and use of macroeconomic theory, data, and interpretations. Moulton and Rosson expressed their concern at the 1990 AAEA Extension Preconference, stating, "For economists, mainly trained in microeconomics, learning the theory and applications required to handle complex macroeconomic issues has been especially difficult" (p. 74). Many AAEA members obtained their graduate training in the 1960s and 1970s, prior to the profession's recognition of the connection between agriculture and macroeconomics. Even recent graduates are exposed to very minor training in macroeconomics, as most graduate programs require only one or two courses in macroeconomics with little or no application content toward agriculture. While macroeconomics texts (e.g., Branson, Peterson, or Dornbusch and Fischer) contain very good descriptions of macroeconomic structure, they are usually devoid of discussions on the political economy and the political process. Agricultural policy courses and perhaps agricultural marketing courses may devote some portion of their classes to macroeconomic linkages and the policy process, but often these are not required courses in most Ph.D. programs in agricultural economics. Thus, many agricultural economists graduate with only bare essentials on the macropolicy process and the relationship of agriculture and the macroeconomy.

A lack of useful sources of information becomes a second major constraining factor to developing effective educational programs on macroeconomics. At the most fundamental level, agricultural economists are not "Fed watchers." While other economists devote considerable professional time and energy to monitoring Federal Reserve policy making, agricultural economists have generally not placed a high priority on this activity. As a profession, we do a considerably better job in information acquisition on trade policy, only because international trade is so important to agriculture. At a different level of information acquisition are the large-scale macromodels. They are important to research programs in government, private firms, and a few universities. However, they often contain assumptions/results that are quickly outdated and sometimes conflict with other models. The information flow seems slow, with little consequent impact on educational programs.

In response to minimal training and limited models, extension is often left to integrating macropolicy into their programming activities in a reactive fashion. That is, extension tends to explain the impact of certain macropolicy changes on the agricultural economy *ex post,* instead of providing information *ex ante*. As a result, this programming method provides agricultural businesses with information which has little or no impact on current business decisions.

The third major barrier extension faces in this area are farmers, agribusinesses, farm groups, rural communities, and others who do not generally identify a clear need for macroeconomics education. Macroeconomics can be an intimidating subject with complex terminology and unfamiliar institutions and actors. This provides a major challenge to extension specialists given their very diverse audiences. Farmers and agribusinesses can generally relate easier to more concrete microeconomic concepts (e.g., profitability, cash flow, optimal input levels) than macroeconomic concepts (e.g., money supply, exchange rates, real interest rates, budget/trade deficits). Agricultural businesses are often short-sighted in their analyses. For example, they realize that profitability may be declining because of lower prices but fail to recognize that prices are falling as a result of weak international demand brought about by an increasing value of the dollar induced by tight monetary policy. Perhaps with some indication of a continued expected escalation in the value of the dollar in their information set, they would have allocated more resources to a less trade-dependent enter-

prise. Thus, besides improving its own knowledge of the relationship of the macroeconomy and agriculture, extension faces a monumental challenge in convincing nonresident students of the importance of understanding macroeconomics.

Survey on Macroeconomic Policy Education in Extension Programming

In order to obtain a broader perspective on these issues, state extension specialists and department chairmen in the 13 states of the Southern region were surveyed.[2] A total of 116 (or 66%) of the 175 state specialists surveyed responded. Eleven of the 13 department chairmen also responded. Survey results are contained in table 1.

Eighty-two percent of the state specialists and 100% of the department chairmen agreed with the statement that macropolicy changes often have a larger impact on the agricultural economy than changes in agricultural policy. Almost 90% of the specialists (100% of the department heads) claimed that extension can offer farm firms and agribusinesses effective strategies for dealing with macropolicy changes. However, 40% of the specialists feel that extension (as a whole) cannot be effective in anticipating major monetary, fiscal, and/or trade policy changes. Department heads were less optimistic, with 64% having doubts of extension being able to anticipate major macropolicy changes. Not surprisingly, over 90% of the specialists and department heads claimed that extension tends to be reactive in its macropolicy education. Even after the macroeconomic changes have occurred, several of the specialists expressed concern regarding the length of time that extension tends to take in developing/implementing programming activities. According to one respondent, "Our record is poor, i.e., when interest rates were 21% we had programs ready by the time they were going south past 15%."

While the awareness of the importance of macropolicy in extension education seems clearly confirmed, it is also apparent that extension economists do not feel totally prepared to incorporate macropolicy components into their programs. Forty-one percent of the specialists claimed that they (individually) do not feel qualified to discuss macropolicy to their clientele. Most specialists claimed that policy specialists should take the lead, and work with other specialists to integrate materials into all extension programming activities. Only 12% responded that macropolicy education should be the primary responsibility of the extension public policy specialist. The consensus was that policy specialists need to work closer with their extension colleagues to incorporate macropolicy education into commodity situation and outlook programs. One respondent claimed ". . . one can't draw by advertising only a macroeconomic meeting. Info has to be tied to a commodity."

Almost 40% of the specialists responded that they currently do not have any programming activities addressing macropolicy issues. Several respondents claimed that they are waiting on signals from the administration before implementing programs. Christenson declares that "the demands on social scientists will not, nor should they, come from administrators. The demands should come from the people who pay our salaries" (p. 15). However, many of the specialists surveyed expressed the belief that many of their nonresident students do not feel a need for macroeconomic education. Comments included that "while they (producers) could benefit from macropolicy education, they do *not* believe this to be true;" "It is just too complex for most people to see any direct impact on their daily lives;" and "I don't think macroeconomic policy education is perceived [as] needed. . . ." Failing to implement programming activities based on the feeling that agricultural businesses do not perceive a need for macropolicy education is the easy way out. Schuh (1990) argues that "those who respond to these obvious new challenges by saying that there is no demand for programs in these areas are abdicating their leadership responsibilities and cheating themselves and their public" (p. 5). As Doering expressed at the 1990 AAEA extension preconference, extension specialists must not fear being risk takers. Given the apparent importance that extension places on macropolicy education, it is critical that we assist our audience in understanding the importance of macropolicy to their business decision making. A couple of the specialists suggested that this type of education be left to the business schools. But will they provide the necessary application programming that agricultural extension has traditionally been able to present?

The survey also asked specialists to identify sources of macropolicy information and to as-

[2] The Southern region consists of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. A copy of the survey can be obtained from the authors.

Table 1. Responses from 1991 Survey of State Extension Specialists and Department Chairmen in the Southern Region on Analyzing Extension's Role in Macroeconomics Policy Education

	Response	Extension Specialists	Department Chairmen
		(%)	
Do you agree or disagree with the statement that macroeconomic policy changes often have a larger impact on the agricultural economy than changes in agricultural policy?	Agree	82	100
	Disagree	13	0
	No opinion	5	0
Do you believe that educational training on macropolicy impacts should be done primarily by extension policy specialists or should other farm management, commodity, and other specialists also include this subject matter in their educational programs?	Extension policy specialists only	12	0
	All specialists	88	100
Do you believe that extension education can be effective in anticipating domestic and foreign monetary/fiscal/trade policy shocks?	Yes	57	36
	No	40	64
	No opinion	3	0
Do you believe that extension can offer farm firms and agribusinesses effective strategies for dealing with macropolicy changes?	Yes	89	100
	No	7	0
	No opinion	4	0
Does extension tend to be more reactive or proactive in macropolicy education (i.e., state what has been the effect of the decline in the value of the dollar rather than anticipating a decline in the value of the dollar and projecting its potential consequences)?	Reactive	95	91
	Proactive	3	9
	No opinion	2	0
Do you believe that you (or your extension faculty in the departmental chairmen survey) are qualified to discuss monetary, fiscal, and trade policy with clientele in your state?	Yes	58	82
	No	40	18
	No opinion	2	0
Do you (or your extension faculty in the departmental chairmen survey) use the information/results produced by macroeconomic models provided by university research colleagues in your macropolicy education?	Yes	29	73
	No	68	27
	No response	3	0
Do you (or your extension faculty in the departmental chairmen survey) use the macroeconomic modeling information/results provided by ERS, FAPRI, or other organizations?	Yes	66	100
	No	32	0
	No response	2	0
Do you believe that this topic will be of minor importance or major importance in your (or your department's in the departmental chairmen survey) extension programs during the 1990s?	Minor	49	0
	Major	48	100
	No opinion	3	0

sess the relative strengths and weaknesses of this information. Sixty-six percent of the specialists claimed they used the information/results provided by the Economic Research Service (ERS), Food and Agricultural Policy Research Institute (FAPRI), and other research organizations, compared to only 29% using the macropolicy information/results produced by university research colleagues. Other cited macropolicy sources included Federal Reserve publications. The *Wall Street Journal*, regional fact sheets (e.g., Southern Region Extension fact sheet series on *Southern Agriculture in a World Economy*), and various USDA policy/trade mail-

ings. The macropolicy materials from these sources were described as "useful in providing direction on alternative policy scenarios" and "providing access to data and policy information in an organized fashion." However, many of the comments were critical. The survey results confirmed the hypothesis that a lot of these materials are (or at least perceived to be) not available on a timely basis. According to one state specialist, "ERS does an excellent job providing historical data and current macro information—the problem is by the time I receive it this information is 6–12 months old. FAPRI is excellent, but I receive their publications only on an annual basis, then I have 11 months to extrapolate." University research was described as "out of date," "too general," "not applied," "too technical," "too much aggregation," and "only focusing on major commodities." Another specialist claimed: "The models . . . are useful in evaluating policy choices but not very useful (directly) in marketing decisions. . . ." Based on these comments, many specialists claimed that extension in many cases will not be able to "extend" the macropolicy research performed by our colleagues but instead will be forced to conduct timely and applied research on macropolicy research specific to their clientele. According to one respondent, "There tends to be a gulf between the theoretical researchers and the applied types. If that void could be bridged, policy education would be easier."

Despite skepticism from a few specialists, overall the survey revealed that specialists and department chairmen believe macropolicy education will be an integral component of extension education during the 1990s. Almost 50% of the specialists claimed that they expect macroeconomic policy linkages to agriculture will be a major component of their individual extension program in the 1990s. One hundred percent of the department heads asserted that this topic will be of major importance to their department's extension program during the 1990s. Therefore, it appears that extension will confront many programming decisions in the next few years regarding the development and implementation of educational programs on macropolicy and agriculture.

Macropolicy Education Programming in Kentucky

In the last five years, the extension agricultural economics program and several related programs within the College of Agriculture at the University of Kentucky have attempted to incorporate some new macropolicy components into existing efforts. Annual agricultural economic outlook programs have provided new attention to monetary and fiscal policy. This has included slides/transparencies explaining some simple basics of macropolicy and interpretations of macropolicy impacts and developments on the general agricultural sector. In addition, commodity specialists (e.g., grains, tobacco, dairy, livestock) have been integrating macropolicy variables (e.g., GATT, exchange rates, interest rates, budget deficit) into their educational programs. The department also sponsors a Top Farmer Workshop annually that integrates macropolicy-related sessions into their workshops. This year a new coordinated set of leaflets is being distributed to Kentucky farmers and agribusinesses that explains the domestic policy process, identifies macropolicy tools and linkages to agriculture, and discusses their impacts on Kentucky farms and rural communities.

At the college level, the University of Kentucky has two separate and very popular leadership programs. Macropolicy is an important component in the curriculum of both programs. One of the programs invites 40–50 farm families annually for a three-day workshop. The major goal of this program is to motivate Kentucky farm families to become more active in leadership roles in their local community, state, and nation. Participants learn about the public policy process and major national and international policy issues affecting agriculture. During the latter stages of the workshop, participants are split into groups to lobby on different national and international policy issues that affect agriculture. This role-playing exercise allows the families to understand better the policy process and observe how conflicts can arise in group policy decision making.

The second leadership program selects thirty young adults for a two-year intensive program on agricultural leadership development. Two groups have completed this program, with a third group now participating in this program. Eleven three-day seminars are offered which cover topics such as communication skills, leadership development, economics, and international trade. A large portion of the program is devoted to policy education. State and national policy personnel (e.g., administrators, elected officials, legislators) are invited to discuss the policy process and policy issues. Professors from the business school discuss monetary, fiscal, and trade pol-

icy, with agricultural economics professors discussing the linkages of these macropolicies on agriculture. In addition to the local training, the participants travel to Washington D.C., and to two foreign countries to observe institutions (e.g., legislative bodies, bureaucrats, the Fed) that affect Kentucky, U.S., and international agriculture. They also meet with key personnel in the U.S. Department of Agriculture (USDA) and legislators to discuss agricultural and macropolicy issues. Upon completion of the program, participants meet as an alumni group every year to be informed of new developments in the policy arena. Several of the participants of these programs are now involved in key leadership roles in farm organizations, commodity groups, and state and national agricultural programs. Following completion of the program, most of participants have become more active in voicing their opinion on local, state, and national policy issues. Participants have expressed that the improved understanding of the policy process and policy implications obtained from both of these programs/workshops have influenced their business management strategies.

The curriculum has also been a target for some new macropolicy education. Given the nature of our university organization, it is not possible for us to have much impact on the design of macroeconomics courses taught in the economics department. However, several undergraduate and graduate classes within the Department of Agricultural Economics (e.g., policy, marketing, trade) have been modified and revised to include more macropolicy issues, topical readings, and research.

Some Strategic Recommendations

Schuh (1990) has declared that a "massive retraining program is needed if extension services are to address the agenda of the future in an effective way" (p. 6). However, we feel a more realistic and pragmatic approach may be some strategic actions designed to enhance individual skills, improve information flows, and reorient educational program goals. Effective leadership to implement these and related changes must come from the profession, not from administrators or graduate directors, as an effective response to those we serve.

At a most basic level, agricultural economists need to approach macropolicy as they have agricultural or natural resource policy. We need to recognize fiscal and monetary policy as political processes in which we have a legitimate role. Once extension economists realize the implications of this, improving extension programs on the relationship of macropolicy and agriculture centers around two phenomena: (*a*) extension economists must initially improve their own understanding of the policy process and macroeconomic linkages to agriculture, and (*b*) extension economists must develop programs which are well received by clientele and eventually impact business decisions.

Improving Extension Educators' Understanding of Macroeconomics and Agriculture

Various opportunities exist to improve extension's understanding of macropolicy issues/impacts. The choice(s) selected will depend upon one's need/interest in obtaining in-depth training, available resources, career level, specialty area, and other factors. Sabbatic leave provides one such opportunity. Doering claims that sabbaticals are as critical to extension staff as health benefits. These sabbatics could be taken within various macropolicy-making bodies, such as the Federal Reserve, Council of Economic Advisors, Office of Management and Budget, the World Bank, or within a macropolicy-making body of a foreign country. Opportunities would also exist to enroll in several graduate level macroeconomic, international trade, or international finance courses during a sabbatic.

While a few economists may use a sabbatic, a more reasonable expectation is to use our professional meetings, regional committee meetings, and conferences/workshops to upgrade our macropolicy skills. This upgrading needs to focus on two areas: the policy-making process and the linkages between agriculture and macropolicy changes. As a profession, we can certainly view professional meetings as vehicles for life-long learning about economics. We can encourage and promote the annual meetings as settings for member-designed training experiences, perhaps on a competitive proposal basis instead of the standing committee recommendations for preconferences. This would allow proactive members of the profession to design and implement continuing education workshops as complements to the other functions of the annual meetings. Opportunities will also exist during regional committee/outlook meetings and workshops to design intensive training sessions. These programs should include personnel from

various macropolicy-making bodies to expose extension educators to new macropolicy resource personnel.

Another opportunity for the profession to improve training is to encourage more educational articles on macroeconomics in *CHOICES*. This periodical has apparently been well received and well read by the profession and agricultural industries. Several recent articles have informed the profession of major macroeconomic issues that impact agriculture. Paarlberg's article on inflation is a prime example, where he argues that monetary factors have been responsible for the major economic events affecting agriculture during the past sixty years.

Independent study provides another means for improving one's knowledge of the relationship of the macroeconomy and agriculture. One place to begin is with the Greider's recent book, *Secrets of the Temple*. This book gives an excellent historical overview on the political economy of the Federal Reserve by examining the Paul Volker term as Federal Reserve chairman. Other educational materials include ERS publications (e.g., *Effects of Monetary and Fiscal Policy on U.S. Agriculture* and *Exchange Rates and U.S. Agricultural Trade*), Federal Reserve publications (e.g., *U.S. Monetary Policy and Financial Markets*), and regional fact sheet series (e.g., *Southern Agriculture in a World Economy*).

A recommendation to improve future extension economists' understanding of the macroeconomy is to influence our teaching colleagues to integrate more macroeconomy materials into our agricultural economics classes. Macroeconomics affects trade, policy, marketing, price analysis, finance, rural development, farm management, and other fields within agricultural economics. Another option would be a seminar (perhaps 1 credit hour) concentrating solely on agriculture in the macroeconomy. We should also provide a means for our international students to educate our domestic students (and ourselves) on the policy process in foreign countries. This additional exposure to the macropolicy process and implications in both domestic and international agricultural markets will enhance the opportunities that our graduates have in extension and other fields.

Programming Strategies to Address Macroeconomic Linkages to Agriculture

Macroeconomics is a very complex subject. In addition, it has varying impacts on different agricultural industries. Thus, successful programs on macropolicy education will most likely have to be delivered to selected (i.e., "targeted") audiences (e.g., farm/commodity groups, business leaders, leadership training groups, county agent training) and discussed in general terms on specific topics (e.g., investment strategies, retirement/estate planning) or specific commodities. Farmers are more interested and more likely to pay attention to the impacts of a given monetary policy change on grain or livestock prices than to general items such as national farm income or U.S. agricultural exports.

Experiences in the past do provide a basis for good learning experiences; however, farmers and agribusinesses want to know how to be better prepared for future policy shocks. Thus, the profession needs to become more proactive in their macropolicy programming. Based on spiraling inflation and indications of a policy reversal at the Fed, arguably extension should have been in a better position during the late 1970s and early 1980s to more effectively warn farmers and agribusinesses of the potentially large negative consequences of the tight monetary policy to follow. Greider recalls the events.

> Starting in November, immediately after Reagan's landslide victory, the Federal Reserve chairman began a series of brooding public lectures, speeches that sounded dark and skeptical compared with the President-elect's engaging optimism. Ronald Reagan spoke confidently of restored vigor and prosperity for the American economy. Paul Volker talked about pain. . . . No one was listening. It was as if Volker were trying to remind everyone what the Fed was in the process of doing—"leaning hard" on the money supply and on the struggling economy, forcing interest rates to extraordinary levels. If Volker's attention was to counter the euphoric promises being made for the new Reagan program, to provoke second thoughts about massive tax reductions, he failed. All eyes were on the Chief Executive. The second-most-powerful officer of government, the independent chairman of the Federal Reserve, was ignored.—(pages 355–56)

Along those lines, extension specialists must become active "Fed watchers." Agricultural economists closely monitor actions affecting agriculture in Congress, but we pay very little attention to the one institution that arguably may have more of an impact on agriculture than any other, the Fed. Thus, we believe that it is imperative that we, like many other capital- and trade-intensive sectors become active "Fed watchers."

We should also try to keep our macropolicy education as simple as possible. Instead of trying

to educate our nonresident students on the "mechanics" of a particular macropolicy variable, perhaps we should concentrate on educating farmers, agribusinesses, and others to closely monitor specific "signals" on the macroeconomic front that may have both short- and long-run implications on agriculture and rural communities (e.g., if the annual inflation rate exceeds 5%, this will be the likely reaction from the Federal Reserve, with this likely effect on interest rates, exchange rates, agribusiness sales, grain prices, tobacco exports, etc.).

One of the major issues identified in the survey that often inhibits effective programs on macropolicy is a lack of timely information. In most cases important macroeconomic data are readily available. Government/Federal Reserve reports are released just like USDA crop/price reports. Extension economists have traditionally evaluated the data made available by USDA reports in making timely price/production/trade forecasts, but in many cases they have simply been reluctant to process the macroeconomics data in making the same forecasts. Information is also readily available in USDA reports (e.g., *Agricultural Outlook*), periodicals (e.g., *Wall Street Journal, Barrons, Business Week*), and private newsletters (e.g., *Doanes Agricultural Report, The Kiplinger Letter*). Some of the data/information may not directly apply to the commodity/topic of interest, but hopefully the macropolicy training discussed above will allow one to become more comfortable processing that data/information so that it does apply to the specific commodity/topic of interest. We can also improve the timeliness and quality of our macropolicy information by networking with the existing establishments and initiating working relationships with economists inside the Federal Reserve system and other federal agencies (e.g., Foreign Agricultural Service, Council of Economic Advisors, Congressional Budget Office, Congressional Research Service).

Finally, more collaboration needs to exist among commodity and policy specialists and also among extension educators and researchers on macropolicy-related issues. Policy specialists can work with commodity and farm management specialists to identify and integrate important macropolicy variables into marketing and management strategies. Researchers involved in macromodeling would likely benefit from extension specialists' ideas on model design, assumptions, and dissemination of results. This collaboration would also benefit extension specialists by providing them with the opportunity to better understand and appreciate the complexities, limitations, and forecasting performance of macromodel building. These efforts should exist across state boundaries to maximize the use of limited resources in macropolicy education/modeling in certain states. This would lead to an increased quantity and quality of educational materials, projects and workshops that extension could provide on assessing the macropolicy impacts on agriculture and rural communities.

Conclusions

Macroeconomic policies will likely have a major impact on agriculture and rural communities during the 1990s. Thus, extension's educational responsibility for macropolicy education is clear: provide farmers, agribusinesses, and communities with an improved awareness and understanding of the impacts of macropolicies and policy making. The net result should be improved decision making and more effective participation in the policy process. Our survey reveals extension economists and their chairmen are aware of the importance of macroeconomic policy changes to our nonresident students. The challenge before us is to pursue a proactive strategy that augments our own professional pool of expertise and improves the effectiveness of our classroom and off-campus educational programs. It is not only possible, but imperative that we rise to this challenge.

References

Barnhart, Scott W. "The Effects of Macroeconomic Announcements on Commodity Prices." *Amer. J. Agr. Econ.* 71(1989):389–403.

Bosworth, Barry P., and Robert Z. Lawrence. "Managing Macroeconomic Imbalances." *Amer. J. Agr. Econ.* 70(1988):1006–12.

Branson, William H. *Macroeconomic Theory and Policy*, 3rd ed. New York: Harper and Row, 1989.

Chambers, Robert G. "Agriculture and Financial Market Interdependence in the Short Run." *Amer. J. Agr. Econ.* 66(1984):12–24.

Christenson, James. "Demands from Extension Administration." *Challenges for Extension Economists in the 1990s*. Proceedings of AAEA Extension Conference, 1990, pp. 15–19.

Doering, Otto. "Adapting to New Roles and New Clientele: How Do We Get There from Here?" *Challenges for Extension Economists in the 1990s*. Proceedings of AAEA Extension Conference, 1990, pp. 27–29.

Dornbusch, Rudiger, and Stanley Fischer. *Macro-Economics*, 2nd ed. New York: McGraw-Hill, 1981.

Frankel, Jeffrey A. "Commodity Prices and Money: Lessons from International Finance." *Amer. J. Agr. Econ.* 66(1984):560–66.

Gardner, Bruce L. "On the Power of Macroeconomic Linkages to Explain Events in U.S. Agriculture." *Amer. J. Agr. Econ.* 63(1981):871–78.

Greider, William. *Secrets of the Temple—How the Federal Reserve Runs the Country*. New York: Simon and Schuster, 1987.

Harris, Harold M., Jr., and C. Parr Rosson, III. "Trade and Policy Ideas: 1990 and Beyond." *Southern Agriculture in a World Economy*. Leaflet No. 11, 1988.

Kitchen, John, and Ralph Monaco. "Effects of Macroeconomic Policies on Agriculture." *Agricultural-Food Policy Review*. Washington DC: U.S. Department of Agriculture Agr. Econ. Rep. No. 620, 27–36.

McCalla, Alex F. "GATT Negotiations and the 1990 Farm Bill." Paper presented to Instituto Nazionale di Economia Agraria (INEA) Rome, Italy, 6 April 1990.

——. "Impact of Macroeconomic Policies upon Agricultural Trade and International Agricultural Development." *Amer. J. Agr. Econ.* 64(1982):861–68.

Moulton, Kirby S., and C. Parr Rosson, III. "International Problems and Program Potentials." *Challenges for Extension Economists in the 1990s*. Proceedings of AAEA Extension Conference, 1990, pp. 73–83.

Orden, David. "Agriculture, Trade and Macroeconomics: The U.S. Case." *J. Policy Modeling* 8(1986):27–51.

——. "National Economic Policies: Effects on Agricultural Trade." *Southern Agriculture in a World Economy*. Leaflet No. 7, 1988.

Paarlberg, Don. "Inflation: It's in the Bloodstream." *CHOICES*, no. 2 (1991), pp. 14–17.

Penson, John B., Jr., and Bruce L. Gardner. "Implications of the Macroeconomic Outlook for Agriculture." *Amer. J. Agr. Econ.* 70(1988):1013–22.

Peterson, Willis L. *Principles of Economics—MACRO*, 7th ed. Homewood IL: Richard D. Irwin, 1989.

Schuh, G. Edward. "An International Perspective of Agriculture in 2001." Paper presented at Symposium on Agriculture for 2001, Lexington KY, 7 May 1991.

——. "Emerging Challenges for Extension in the 1990s." *Challenges for Extension Economists in the 1990s*. Proceedings of AAEA Extension Conference, 1990, pp. 1–6.

——. "The Exchange Rate and U.S. Agriculture." *Amer. J. Agr. Econ.* 56(1974):1–13.

Starleaf, Dennis R., William H. Meyers, and Abner Womack. "The Impact of Inflation on the Real Income of U.S. Farmers." *Amer. J. Agr. Econ.* 65(1985):348–89.

Tweeten, Luther. "Macroeconomic Linkages." *Farm Policy Analysis*, pp. 165–91. Boulder CO: Westview Press, 1989.

Macroeconomic Policy Research: Discussion

John B. Penson, Jr.

I am pleased to participate in this invited paper session and strongly endorse what I perceive to be the premise underlying the session; namely, that we as a profession need to focus more of our teaching, research, and extension resources on the "macroeconomics of agriculture." This point was eloquently made by Ed Schuh at these very meetings some fifteen years ago. Schuh's point was that our sectoral heritage and research emphasis "has caused neglect of the linkages of agriculture with the rest of the economy," and that "if there has been one major failing over the years, it has been this failure to grasp fully the macroeconomics of agriculture (p. 810). While the profession has made some strides in macroeconomic policy research as it applies to agriculture over the last fifteen years, the task is a never-ending one, and the field does not suffer from overcrowding.

The title of this session is "Improving Macroeconomic Policy Considerations in Agricultural Research and Education." With this in mind, let me make some remarks about the paper I am supposed to discuss, one or two remarks about the paper I was not asked to discuss, and finally present a few thoughts on the topic addressed by this session.

Comments on Paper by Orden and Fisher

I enjoyed reading the paper by Orden and Fisher. The first third of the paper gives the reader some background on the New Zealand and Australian economies. Orden and Fisher next present a recent development in time-series analysis that estimates cointegrating relationships, and then use it to evaluate dynamic and long-run responses to shocks to the New Zealand and Australian economies. Space consideration no doubt forced the authors to ask the reader to spend some time in the library, not an altogether bad place to be in Texas during the summer. Unfortunately, sixteen of the nineteen references cited by Orden and Fisher were of New Zealand or Australian origin, and many consisted of either speeches, conference proceedings, or forthcoming manuscripts. Orden and Fisher's discussion of cointegration systems in aggregate economic analysis for the economies of New Zealand and Australia does illustrate how time-series analysis can contribute to an understanding of macroeconomic outcomes. For example, their results underscored the significant role wheat exports play in the long-run equilibrium of the Australian economy and identified how these two economies are both similar and yet different from a time-series perspective. Had I been asked as an anonymous journal reviewer to critique this paper in the context of evaluating aggregate statistical relationships for the New Zealand and Australian economies, I would give it a thumbs up, particularly if the properties of the model were presented in more detail.

I must admit, however, that I was surprised at the general orientation of the Orden and Fisher paper given both its title, "Macroeconomic Policy and Agricultural Economics Research" and the general theme of this invited paper session. Knowing Orden's interest in time-series modeling, I half expected a discussion of the relative merits of times-series versus structural estimates of macroeconomic relationships and the contributions both modeling approaches make to the decisions reached by public and private decision makers. Furthermore, I expected a discussion of the major linkages between U.S. agriculture and the general economy, and the progress researchers have made, if any, in investigating these linkages since the papers by Schuh, Tweeten, Penson and Hughes, and Penson and Gardner in earlier issues of the *AJAE*.

A Few Thoughts on the Paper by Snell and Infanger

This paper raises some interesting questions. For example, I found the results from the survey they

John B. Penson, Jr., is Stiles professor, Department of Agricultural Economics, Texas A&M University.

discussed very interesting, including the claim that extension programs "will not be able to 'extend' the macropolicy research performed by our colleagues but instead will be forced to conduct timely and applied research . . . specific to their clientele." Clearly, this is a serious issue that needs addressing, particularly if 100% of the department heads surveyed see macroeconomic policy as being very important in the 1990s. I would like to have seen some attention to the effect that adverse interest rate trends in a variable rate mortgage environment have upon the financial position of farmers and why sound investment and financial analysis is needed in a capital-intensive sector such as agriculture known for its asset fixity and chronic excess capacity.

Finally, I would like to have seen more attention given to the current adequacy of instruction in macroeconomic theory and application in our undergraduate and graduate classrooms given the title of this session. Until we place greater emphasis on macroeconomics in our curriculums, it is hard to expect our graduates to feel excited about conducting education programs on the impacts of macroeconomic policy.

Lessons Learned from the 1980s

Agriculture is dependent on the supply of goods and services provided by other sectors of the economy as well as on the domestic and export demand for its product. The market-clearing prices in these various markets go a long way toward determining what happens to the annual economic performance and financial position of farmers. This includes not only the prices in product markets and manufactured farm input markets but financial markets (where farmers must borrow to operate, modernize, and expand their operations), farm real estate markets, and foreign currency markets as well. The magnitude of the financial crisis experienced by farmers during the 1980s, which can be linked to unexpected high interest rates from contractionary monetary and expansionary fiscal policy, underscores the importance of the topic we are addressing today.

Expanded Research Efforts

Numerous studies over the years have investigated the statistical properties of the demand and supply for specific commodities at both the farm and retail levels. The last fifteen years, however, has seen the development of a number of structural sector models, like the AGSIM model developed by Taylor, that endogenize demand and supply relationships across major crop and livestock categories but are solved on a stand-alone basis *vis à vis* the general economy. We have also seen the development of econometric, input-output, and computable general equilibriums models in recent years that endogenize the linkage between agriculture and the general economy in one fashion or another (Penson and Gardner). And some institutions, like FAPRI, have expended considerable resources to model worldwide commodity outcomes, and what this means for U.S. agriculture. Finally, there are a growing number of time-series studies exploring the relationship between macroeconomic policy and specific variables in the sector and general economy. All of these models attempt to capture the effects of changes in macroeconomic policy on agriculture, but in varying degrees and style. Some capture these relationships in a fully simultaneous fashion, while others take either a recursive, or a stand-alone, approach. Some endogenize the money and capital markets where monetary policies are introduced, while others assume trends in exogenous interest rate and exchange rate variables. While some of us might prefer one approach over another, all perspectives should be welcomed and debated. The important point is that we have begun to focus more resources toward furthering our understanding of the interaction between agriculture and both the domestic and world economies. We need more Ordens and Fishers exploring the unique effects that macroeconomic policies have upon agriculture.

Finally, more needs to be done to disseminate the lessons we learn in research to a broad-based audience. Emphasis should be placed upon changes in prices, supply and disappearance, net income, and farmland values resulting from macroeconomic policy shifts as opposed to point forecasts which can become quickly outdated as world events unfold. And, while it would be wrong to base policy decisions totally on what these models tell us about alternative policy impacts, they can provide a useful input to public and private policy decisions under a given set of assumptions. There can be little doubt our choice of macroeconomic policy will have a major impact on the economic performance and financial health of agriculture in the 1990s. Hopefully our proactive efforts will lead to informed decisions.

Analyzing Extension's Role in Macroeconomic Policy Education: Discussion

Gary F. Fairchild

For the past fifteen years, prominent members of the agricultural economics profession have been noting the importance of macroeconomics to the agricultural economy. Moreover, we are a large profession which professes to be concerned about addressing and solving problems and providing information for decision makers in the agricultural sector. And yet, we collectively seem to be relatively uninvolved with macroeconomics, except of course to talk about it. So what is wrong with this picture? If macroeconomics really is so important to the agricultural sector, really does make a difference, and really is useful to firm and industry decision makers, then why the apparent gap between our words and our actions?

My objectives today are to (*a*) comment briefly on the strengths and weaknesses of the Snell and Infanger paper, (*b*) share my viewpoint on extension's role in macroeconomic policy education, and (*c*) discuss what a concerned extension economist needs to consider before deciding to make an investment in macroeconomic extension programs.

After briefly establishing the importance of macroeconomics to agriculture, the authors detail three major issues and concerns surrounding the incorporation of macropolicy into extension programs on a "stand-alone" or "component" basis. These are (*a*) our perception, understanding, and use of macroeconomic theory, data, and interpretations; (*b*) a lack of useful sources for information; and (*c*) clientele groups who do not generally identify a clear need for macroeconomic education. One of the paper's strongest contributions lies in the framing of the issues for discussion. I only wish they had expanded this section to include more depth and breadth.

Professional Correctness

To economists, the letters "PC" tend to denote "personal computer." However, in recent years, PC has become associated with political correctness. I would suggest that PC can also refer to professional correctness. Currently, it is professionally correct to assert that macroeconomic policy is important to and exerts a major influence on agriculture. It is also professionally correct to suggest that we should be doing a better job of integrating macroeconomics into research and extension programs. In a way, Snell and Infanger do not disappoint me. They have a knack for observing the obvious. They have said all the right things. They have carefully injected their paper with PC and wrapped it in the mantle of the profession. This puts a discussant at somewhat of a disadvantage, professionally speaking. However, the authors are to be commended for their efforts in dealing with a difficult and elusive topic. They provide a thoughtful paper. While my response is generally positive, I have some concerns. These concerns focus on the tone of the paper and the lack of specific evidence of successful macroeconomic extension programs.

An Emotional Issue

As I talk with colleagues about the role of extension in applying macroeconomics to the agricultural sector, I have been struck by the strongly held, divergent opinions on the subject. In fact, a casual conversation can cause tempers to flair. Macroeconomics is indeed an emotional subject. I can still remember crying as I read and reread Patinkins' book, *Money, Interest and*

Gary F. Fairchild is a professor and extension economist, Food and Resource Economics Department, University of Florida.

This is Florida Agricultural Experiment Station Journal Series No. R-01785.

The comments, ideas, and insights of Geoff Benson, Hal Harris, Parr Rosson, Larry Sanders, and University of Florida colleagues who prefer to remain anonymous are much appreciated by the author.

Prices. I also remember bouncing it off the wall a few times.

The issue at hand seems to be whether we really know what to tell decision makers that will make a difference. A number of associated issues surround this core question including: (*a*) the general disarray of macroeconomic theory which fails to instill confidence in the casual user, including agricultural economists; (*b*) the complexity of issues and topics; (*c*) the need for, but reluctance of, agricultural economists to make investments in intellectual capital in macroeconomics; (*d*) the difficulty in getting ideas across to audiences; (*e*) general awareness versus specific applications; (*f*) short-run versus long-run considerations; and (*g*) an uneasy feeling about the true value of macroeconomic information to audiences.

The Economic Landscape

My high school class motto from 1960 was, "The higher we climb, the broader the view." This motto still has application today as we survey the economic landscape. First, let us assume a mountain of macroeconomics and a valley of microeconomics. Now, let us climb Macro Mountain. As we breathe the rarified air at this altitude, we can clearly see the importance of macroeconomic policy to all that stretches below. While Macro Mountain is sparsely populated, it is still of vital importance to the residents of Micro Valley. From the mountain we can see the macroeconomic policy dam which protects the valley from flooding. Those working in the valley cannot see the dam. The view from the mountain can provide the valley with an early warning when the dam breaks. Sometimes the impacts can be minimized. Sometimes disaster can be avoided.

In addition to an early warning system to prevent economic disaster, the real value of macroeconomics may lie in the way risk is viewed in the decision-making process. As we help managers assess risk, providing some perspective on the risk introduced through macroeconomic variables allows for a more realistic assessment of the decision-making environment. Ignoring sources of risk embedded in macroeconomic variables encourages decisions based on an underestimate of true risk.

Ultimately, discussions of the application of macroeconomics to agriculture center on policy. Not surprisingly, policy permeates the paper by Snell and Infanger. Extension economists working with farmers, agribusinesses, and other rural decision makers would be ill-advised to ignore the influence of macroeconomic policy variables on the decision-making environment. However, they also need to be aware of the limitations associated with macroeconomic policy. Somehow, I do not think that will be a problem.

I agree with Snell and Infanger that most extension economists would benefit from an improved understanding of macroeconomic policy. I would further agree that many extension programs would benefit from increased attention to macroeconomic variables. I would caution, however, that there are costs associated with these benefits which need to be specifically addressed. Not everyone needs to be working in macroeconomics, but some do. There is probably a need for more of us to focus some attention on macropolicy issues. There is definitely a need for the rest of us to listen.

Priorities and Carrots

Changes in program emphasis in the past have resulted from varying combinations of astute problem identification and economic incentives (e.g., salary and support funding). While we seem to be long on problem identification with respect to macroeconomics, we may be a little short on incentives. What incentives are being offered for retooling and changing gears, for taking the time and attention from other activities to become comfortable and conversant with macroeconomics? In spite of Snell and Infanger's creative suggestions for improving extension educators' understanding of macroeconomics, the questions of incentives and choices have been generally ignored.

Assuming a general absence of underemployment among extension economists, devoting time to retool and expand activities in macroeconomics means having to cut back or eliminate something else and probably means getting further behind in other assigned activities. Choices will have to be made. What are we going to drop as we expand into macroeconomics? In this era of downsizing, or at least reduced budget support, it seems that benefit/cost analyses and explicit prioritization would be in order before we all answer the siren song of macroeconomics. These are decisions which must be addressed by both academic departments and individual extension economists.

Similarly, incentives must be addressed. With 100% of the department chairs in the southern

region indicating that macroeconomic policy will be of major importance in their department's extension programs during the 1990s, I am sure that academic rewards and carrots will be forthcoming. For, without such incentives, the more likely outcome will be reflected in the 49% of extension specialists responding to the survey who believe that macroeconomics will be of minor importance to their extension programs. And this may be optimistic.

Final Comments

In spite of some individual inertia, our profession has a pretty fair track record for flexibility. We have witnessed several shifts in emphasis over the past four decades. From our pre-World War II roots in farm management, the 1950s saw a growth in marketing, followed by international development in the 1960s, community and rural development in the 1970s, and natural resources and international trade in the 1980s. Will the 1990s be the decade of macroeconomics for agricultural economics? I am more hopeful than I am optimistic, in spite of the positive tone of the survey results reported by Snell and Infanger.

Agricultural economics is a pretty big profession, so it is quite possible that much more macropolicy education is going on than we collectively realize. We have not been very good at communicating and sharing written educational materials. If anyone has a really successful extension program in macroeconomics, with solid, measurable, useful impacts, please let the awards committee know about it. You will be in great demand. Perhaps a starting point would be a survey of the entire membership as to how macroeconomics is integrated into extension programs, along with specific ideas for the future. Copies of publications, presentations, overheads, etc., could be returned with the questionnaire. The results of the survey, program ideas, and materials could form the basis for a display, poster session, policy outlook session and/or a preconference at the AAEA meetings. This could be a project for the AAEA extension committee. Similar opportunities may also exist for the teaching and research functions.

If we are to witness improvements in understanding and application of macroeconomics in our profession in the 1990s, we need to stop talking about how important it is and jump-start individual agricultural economists. We can no longer hide behind the anonymous veil of the profession. Individuals must step forward with real programs for real people. The survey results from the southern region are optimistic, and certainly Snell and Infanger provide us with the warm glow of optimism. I hope this optimism is warranted. I hope they are right.

Toward Increased AAEA Involvement in Economics Education: Research Findings and Opportunities
(Leo Polopolus, University of Florida, presiding)

Economic Literacy: A Marketable Product for Land Grant Universities

Kimberly Reda-Wilson

Economic literacy, to which agricultural literacy is inextricably connected, affects the social fabric on which our country is founded. Unfortunately, the present levels of economic/agricultural literacy are extremely low and have yet to be addressed by the land grant university system, Cooperative Extension Service (CES), agricultural economics departments, and the American Agricultural Economics Association (AAEA).[1]

Inasmuch as a programmatic effort in economic education is compatible with our values, goals, and structure, we should act more responsibly toward reversing the trends of economic illiteracy. Recognizing the need for economic education, however, is only a first step in the process. As professionals, we are challenged with the unprecedented need to market our product and to create a demand for our services (Khol, Shabman, and Stoevener). Finally, we are challenged to make the decision to commit resources toward improving economic education.

The Problem—Economic Illiteracy

It all begins in the kindergarten classroom, long before college, which only a small percentage will attend. Fewer yet will major in agricultural economics. Somewhere into the academic year, kindergarten teachers begin to espouse recycling because "it is good." Soon the majority of kindergartners are blindly acclaiming recycling because the kindergarten teacher, the nonfamily person most respected in their lives, says it is good. As the year progresses, the students are shown a melodramatic filmstrip of a young elephant calf feeding the last time from the still-warm corpse of its mother elephant who has fallen prey to poaching.

Some may ask, "What is wrong with enlightening our young minds with dynamic global issues of the day?" It is not objective education. When our young people are persuaded to view certain issues based on one set of emotional feelings, they are not presented with any socioeconomic perspectives, those driving forces behind humans' actions. Too often, instructors' presentations are not balanced with discussions about the costs of recycling or with the explanation that it is people's demand for ivory and the consequent desire for profit by supplying that good that is causing the death of elephants.

As students proceed in their schooling (that is, if they do not drop out—Sharradan estimates a dropout rate of 700,000 students per year), their level of economic knowledge remains low. Research on fifth to twelfth grade students indicates that, while there are significant differences on the test scores for students with and without economics, the final level of performance is low for all students (Walstad and Soper, Soper and Walstad, eds.).[2]

Though agriculture provides our basic "economic needs" for food, clothing, and shelter, its literacy fares no better than economics. Other dimensions of agriculture (technological, sociological, political, international, and environmental, to mention a few) are inherently related to economics; yet, the National Research Council (NRC) has concluded that "most Americans know very little about agriculture, its social and economic significance in the United States, and particularly its links to human health and environmental quality."

Kimberly Reda-Wilson, previously co-director of the Virginia Polytechnic Institute and State University's Center for Economic Education, is currently a private economic education consultant.

The author gratefully acknowledges the inspiration, support, and phone card provided by Sandra S. Batie and for the statistical analysis provided by Daniel B. Taylor.

[1] For the sake of brevity, in the remainder of the article, I will use the pronoun "we" to refer to this group of organizations.

[2] Normed tests measure students' knowledge of economics from an overall perspective and across major economic concepts.

Lack of Economic Mandates and Teacher Training

Certain economic concepts are fundamental for understanding the rationale for why all economic systems exist. Thus, it would appear that economic education is indispensable to citizenship education and therefore should be considered basic education in the schools (Miller). Not so. Only twenty-eight states mandate that students receive some form of economics instruction, and only sixteen states require at least a one-semester course in economics for graduation (Highsmith).

"It is serious enough that our high school graduates are failing in measures of basic economic literacy. It is unconscionable, however, to continue, without correction, programs and practices that produce teachers who themselves have insufficient knowledge in economics, whether they are obligated to teach that subject matter field or not" (Hermanowicz). Thus, a corollary to low student performance in economics is a lack of economic requirements for elementary/secondary instructors and a subsequent lack of training finances. Three out of four of our elementary and secondary school instructors have never taken one course in economics, business, or finance (JCEE 1989). Only nine of the twenty-eight states that mandate economic instruction provide funding support for teacher training (Highsmith). Common sense tells us that economics will not be taught and economic literacy will be low.

Following the same vein of thought, virtually no formal effort is made to educate teachers about agriculture except for vocational agriculture. Even the teacher education programs in agriculture tend to be weak in the areas of economics, marketing, management, international trade, and public policy (NRC).

The Solution: Economic Education

Because socioeconomic factors remain a stranger through most, if not all, primary and secondary education, our society has an economically illiterate group of students. This does not have to be the case. Research has proven that certain economic concepts can be understood as early as kindergarten (K) (Schug, Kourilsky and Graff, Kourilsky). The ability to apply economic reasoning challenges students to go beyond their initial judgments. Economic reasoning as a paradigm helps "students recognize and explain cause and effect relationships—especially situations which seem puzzling or which challenge currently accepted beliefs" (Schug and Wentworth).

"The primary purposes of economic education are to provide individuals with the knowledge and skills they need to make personal economic decisions and to participate in the process of social decision making" (Gilliard et al.). The goal of agricultural literacy is to produce informed citizens able to participate in establishing the policies that will support a competitive agricultural industry in this country and abroad (NRC). By incorporating the two, I believe economics and agriculture can be mutually enriched. For purposes of this paper, agricultural education (literacy) is viewed as a complement to economic education (literacy).

Informed decision making is vital to the health of democracy. The National Council for the Social Studies (NCSS) Task Force on Scope and Sequence precisely states the importance of decision making:

> Citizenship means that an individual is fully franchised as a member of a political community. The rights, duties, responsibilities, and entitlement embodied in the franchise apply even-handedly to those who have the abilities and skills needed to participate in the social life of the group. But what becomes of those who do not acquire such abilities and skills? Moreover, can a society that assumes responsible citizen involvement in decision making survive if members do not, will not, or cannot participate in such decision making?
>
> —(Gilliard et al. quoting NCSS)

Schug reviewed approximately twenty-five developmental studies to illustrate that students economic thinking follows a developmental pattern, improves with age and formal instruction, and that "staff development appears to be an effective method for improving economic understanding of students." "Further, inasmuch as the acquisition of economic understanding is a developmental process, economic education should begin in the early grades. To assure the availability of economic education to all students, the teaching of economics should be integrated into the required social studies program for elementary and secondary schools" (Gilliard). Similarly, the NRC has recommended that all students in grades K–12 should receive some systematic instruction about agriculture by its incorporation into existing courses.

Who Is Contributing to the Solution

The American Economics Association (AEA) and the Joint Council on Economic Education (JCEE) have given life and energy to economic education. The JCEE network, consisting of a national office, 50 State Councils on Economic Education, and 271 university-based Centers for Economic Education, is the premiere organization in the country for implementing a comprehensive economic education program in grades K–12. The JCEE national office provides economic education programs, materials, and services to the affiliated council and center network. State councils adapt, coordinate, and promote these programs and services to fulfill the educational needs of their state. Governed by their individual board of trustees, the state councils also serve as the fund-raising arm of the council and center organizational structure within a state. University- or college-based centers provide local or regional teacher-training programs, provide consulting services, conduct research, and develop and disseminate "localized" curriculum materials. JCEE estimates that 40% of the nation's students are enrolled in their Developmental Economic Education Program (DEEP) systems. This effort is enhanced by an extensive teacher training program which reaches 120,000 teachers per year (JCEE 1989).

There is a rich historical evolution of the AEA's position on economic education (Saunders). From their initial yet intermittent roundtable discussions as early as 1895 through 1950 to the present standing Committee on Economic Education (CEE), AEA's philosophy has evolved into a strong, active, project-oriented one. Presently, the AEA CEE is commissioned to arrange one session on economic education at each AEA annual meeting, and the proceedings are published accordingly. AEA is officially affiliated with the JCEE and has three representatives on the board of trustees. Collaborative efforts between AEA and JCEE have served to legitimize economic education as a subfield within economics, as is notably evidenced by the arrival of the *Journal of Economic Education*. From the journal's inception, the number of economic education research articles dealing with precollege subjects has more than tripled 1963–1990. That trend is continuing; of the sixty-one (nongeneral) research articles recorded in 1990, 89% were on precollege subjects compared to 42% during the 1980–1990 period (Marlin and Durden).

We Are Not Fully Involved

To date, the land grant university system and cooperative extension have not fully contributed toward the expansion of economic education. Currently, 53% of the land grant campuses do not have a JCEE affiliated state council or Center for Economic Education. This deficiency is particularly noticeable for some states that are endowed with JCEE centers (California, 18; Missouri, 10; New York, 17; Pennsylvania, 10; and Texas, 13). Though 47% of the land grant universities have a JCEE affiliate on campus, (4% have a state council only, 27% have a center only, and 16% have both a council and center), those affiliates rarely work with agricultural economics departments, vocational agriculture, 4-H, Future Farmers of America (FFA), or Ag in the Classroom (AITC).

Based on departmental assignment of JCEE Centers, the SCSC[3] and Virginia Tech centers are the only two whose addresses make reference to agriculture (JCEE 1991). Virginia Tech (VT) shares an exceptional story. Subsequent to the appointment of a 4-H youth specialist in the agricultural economics department, an inactive Center for Economic Education was transferred from the economics to the agricultural economics department. An organizational structure existed via the Virginia state council through which the VT center could coordinate and carry out activities with the other seven Virginia centers. Thus, VT was instrumental in targeting, on a statewide basis, audiences like 4-H, vocational agriculture, FFA, and AITC which had not previously been addressed by the Virginia economic education network. VT was also the first JCEE affiliate to utilize the CES satellite communications system to broadcast a nationally televised economic education workshop in 1990. The broadcast significantly impacted the number of 4-H youth enrolled in the Stock Market Game (SMG). (Virginia was the first state to accept the JCEE-sponsored SMG program as an official 4-H project.)

AAEA's historical position on economic education resembles a hands-off policy, unlike that of AEA which is best expressed by the AEA Ad Hoc Lewis Committee in 1956: "The economics profession will greatly misjudge its responsibil-

[3] South Carolina State College (SCSC) has the only Center for Economic Education located at an 1890 land grant institution. There are no state councils.

ity in our society if it continues its long-time indifference to the place and problems of economics in the schools and evidences professional concern for economics only at the college and graduate levels" (Saunders).

More recently, an AAEA ad hoc Committee on Economic Education (CEE) was appointed (in 1989) to analyze the feasibility of AAEA establishing an affiliation with the JCEE. After reviewing AEA's success story, the ad hoc CEE requested the scheduling of an invited paper on economic education at the 1991 annual meeting. The ad hoc CEE was reappointed for 1990 and an invited paper session and organized symposium, both entitled "Toward Increased AAEA Involvement in Economic Education," were approved for 1991. While this AAEA board decision reflects an initial interest, such action awaits professional performance.

Further Evidence: We Are Not Involved

The AAEA ad hoc CEE surveyed all JCEE councils and centers to assess the extent to which they (JCEE) did or did not work with the youth audiences, 4-H, vocational agriculture, FFA, and AITC. In addition to personal observations, and given a survey return rate of 32% for the councils and 23% for the centers, I believe the responses adequately represent the population surveyed in order to derive several relevant implications to our profession.

Compared to the centers, a higher percentage of state councils worked with the aforementioned groups; though, on an aggregate level, that activity has been minimal in the past three years (table 1). For example, three councils accounted for 93% of the activity with AITC over the past three years (table 2). The national average AITC contact per center was approximately one time per year and less than that for 4-H. While the comparative level of JCEE involvement with vocational education increases dramatically, it is probably safe to extrapolate that JCEE involvement with "vocational agriculture," a program within vocational education, is extremely low: 75% of vocational agriculture students are FFA members (NRC), and only 19% of the councils and 3% of the centers have worked, or have attempted to work, with FFA very few times over the past three years.

Seventy-five percent (61%) of the councils (centers) responded "yes" to the question, "Are you familiar with CES?", while only 50% (36%) responded correctly that CES was available in 100% of their state's counties. While 69% (37%) of the councils (centers) responded positively to the question, "Have you worked with your counterparts in agricultural economics departments?", the qualitative responses were more telling. That level of involvement rarely dealt with economic education as described in this paper.

Fifty-six percent of the councils felt that "teacher training" was the most efficient method of delivering economic education to the majority of U.S. students, whereas centers rated both "teacher training" (37%) and "infusion of economics into the curriculum" (23%) as the most efficient methods. Both councils and centers rated the "infusion of economics into the K–12 curriculum" as the most important level of economic education needed by the general population.

Based on the JCEE categorization of twenty-

Table 1. Percentage of JCEE Network Affiliates Which Have Worked or Attempted to Work with Youth Groups, 1989–91

	AITC[b]		4-H		Voc. Ed.[c]		FFA[d]	
	State Council	Center	State Council	Center	State Council	Center	State Council	Center
Have worked or attempted to work with[a]	50	26	50	22	88	50	19	8
If not involved, would be willing to work with	75	89	63	76	100	100	100	84

[a] Work with or attempted to work with defined as deliver programs, consult, develop material, conduct research, evaluate, or test.
[b] Agriculture In The Classroom.
[c] Vocational Education (not to be interpreted as vocational agriculture).
[d] Future Farmers of America.

Table 2. Number of JCEE Affiliates and Estimated Contacts with Audiences, 1989–91

	AITC[a] Contact	4-H Contact	Vocational Education[b] Contact	FFA[c] Contact
(Number)/state councils	(5) 91*[d]	(6) 8	(7) 36	(1) 1
(Number)/centers	(13) 36	(13) 22	(24) 144**	(3) 30***
Total contacts	127	30	180	31

Note: Table 1 percentages may not correspond to table 2 totals because of missing variables.
[a] Agriculture in the classroom.
[b] Vocational Education (not to be interpreted as vocational agriculture).
[c] Future Farmers of America.
[d] Single asterisk indicates that three state councils accounted for 85 contacts; double asterisk indicates three centers accounted for 94 contacts; triple asterisk indicates that one center accounted for 24 contacts.

two economics concepts (Saunders et al.), council and centers consistently rated fundamental economic (particularly scarcity and opportunity cost) and microeconomic concepts (demand and supply) as the most important concepts to teach given a scarcity of available class time. Councils and centers rated fundamental and microeconomic concepts as those best illustrated by application to agriculture (table 3). The importance of fundamental economic concepts were rated overwhelmingly higher than agriculturally related issues (table 4).

Implications

Over all, data indicate that agriculture's traditional youth audiences have not been targeted by the economic education network, even though all of these groups have an existing infrastructure to support such activity. Fortunately, it bodes well that the JCEE councils and centers are willing to become involved with new audiences.

The JCEE network is not fully aware that extension, through its 4-H program, for instance, can potentially infiltrate areas of a state not being served by economic educators. Also, agricultural economists are not part of the cast of collaborative players engaged in the formal delivery of economic education. Collegialism, effective and positive networking within a profession, does not extend from the JCEE into the agricultural domain. Even within agriculture, "it is rare for high school vocational agriculture teachers to help their colleagues incorporate instruction about agriculture into history, science, languages, and other courses" (NRC). Agricultural economists and economists have a great deal to offer one another if given a model to share and articulate ideologies, materials and resources, experiences, and concerns and if given an opportunity to make collective decisions regarding effective economic education (Kourilsky and Quaranta).

Economists' high ranking of fundamental economic and microeconomic concepts is consistent with the data indicating that students perform poorly in macroeconomic and international areas (Walstad and Soper; Soper and Walstad, eds.). Perhaps, agriculture can find a niche insofar as the recommendation has been made that more curriculum materials on macroeconomics and international economics are needed as well as intensive teacher training in these areas (Walstad and Soper).

Table 3. JCEE Affiliate Ranking of Economic Concepts Best Illustrated by Application to Agriculture

	Economic Concepts[b]	
Ranking[a]	State	Center
Number 1	1,8	1,8
Number 2	2,9	8
Number 3	6[c]	8

[a] Rated by more than 15% of the population.
[b] 1 indicates scarcity; 2, opportunity cost; 6, exchange, money, and interdependence; 8, supply and demand; 9, competition and market structure.
[c] Thirteen percent ranked productivity and role of government.

Table 4. JCEE Affiliate Ranking of Topics in Terms of Educational Importance within Economic Education

4	International trade
3	Competition and market structure
6	Global and domestic environmental issues
5	Economic systems
8	Economic development (rural communities)
9	Food and water safety (reduction of chemical contamination)
7	Financial markets
1	Scarcity
10	Family farm profitability
2	Opportunity cost and trade-offs

Note: State council and center ratings were the same.

Economic educators should rank the importance of economic concepts higher than a given issue. Economic concepts are the tools enabling an economically literate person to make reasoned judgments about any economic issue, whether it be recycling, family farm profitability, or any other.

Why We Should Be Involved

Looking to the 1990s, rapid change will incessantly challenge the political legitimacy of public support for the land grant system and CES. Schuh contends that land grant universities "have lost much of their sense of mission and faculty no longer feel they have a responsibility to engage in outreach programs." To engage as active participants in economic education, we have a chance to revitalize the original land grant mission, as well as revitalize agricultural programs which, at one time, were such a distinct success among youth and had an uncommonly positive impact on adults.

Administratively, there are documented stances and resources that the land grant system can utilize to catapult the economic education movement. According to the National Association of Economic Educators (NAEE) 1990 Network Survey, 17% of the respondents described their JCEE center level of program activity as "modestly active" or "inactive." Reasons cited for inactivity included lack of release time, no support staff, lack of college/university support, and insufficient funding. Also, recall that 53% of the land grant institutions have no JCEE affiliate on campus.

Utilizing extension as a community-based educational network to share university resources, agricultural economics departments could be the catalyst to significantly increase the JCEE delivery system. Contrary to Buckles' acclaim that "in no other discipline does there exist a delivery system like the one in economics," extension has an outreach component in every county in every state.

Economic and agricultural literacy will be key factors affecting decisions made in the policy arena which will increasingly impact the issues of food, fiber, and natural resources. While agriculture has economic, social, and environmental significance, it should be subsumed in a basic economic understanding. Agricultural economists, who traditionally have been a source to communicate broadly with the general public (Doering), are naturally gifted to provide leadership, guidance, and expertise to a new program initiative in economic education.

A Market and a Product: Who Will Supply It?

Current JCEE President Stephen Buckles acknowledges that, even though empirical research indicates that DEEP is an effective program to increase economic literacy, efforts must be made to improve it. He underscores three primary tasks to be undertaken by the JCEE: enhancement of national awareness and commitment to economic education, the development of a national economic education curriculum, and enhancement of the economic education delivery system. He carefully notes the need to generate more resources for JCEE state councils and centers as well as the need for the JCEE to work more closely with other organizations.

There is a market for increased economic literacy. Who or what can best enhance the present efforts of the JCEE? I propose that the land grant system, CES, agricultural economics departments, and the AAEA provide resources for economic education and coordinate efforts with the JCEE. Considerations warranting our commitment to economic education are ample. Paraphrasing Lewis, certainly nothing that [agricultural] economists undertake is prompted by a purpose worthier than the improvement of economic education in the schools and the development of economic understanding among all of our people; and certainly nothing that [agricultural] economists undertake is more professionally challenging; and G. L. Bach, "It is simply irresponsible for [agricultural] economists to say we should not bother to teach economics in the high schools" (Saunders, quoting Lewis and Bach).

How We Should Be Involved

It cannot be assumed that we will be invited to work with the JCEE. We must market our product and create a demand for our services. There are three levels from which to proceed: organizationally, programmatically, and philosophically. An AAEA affiliation with the JCEE would create the organizational scheme allowing for an administrative and functional structure to coordinate and carry out national economic education activities. Following an AAEA/JCEE affiliation, AAEA should assess methods to encourage land grant institutional endorsement of economic education (a necessary condition

precluding departmental commitment) and a means by which agricultural economics departments could receive assistance in their development of economic education programs.

Programmatically, agricultural economics departments should establish contact and cooperatively work with their respective state council. If a center is not located on the land grant campus, the establishment of one should be deliberated. Upon an affirmative decision to devote departmental resources to economic education, a plan of action should include, but should not be limited to, the following: (*a*) Target a specific clientele (e.g., 4-H, FFA). (*b*) Determine how existing economic education material can fit into the clientele's curriculum. (*c*) Consider the associated teacher (leader) training requirements with special attention to in-service programs currently being conducted at the land grant campus. (*d*) Develop a plan to market an economic education program to the targeted clientele.

Philosophically, any new economic education initiative should be guided by current educational reform imperatives of which Kourilsky and Quaranta have identified four: collegialism, an interdependent and cooperative connection among all economic educators; professionalism, a commitment to a common set of goals, autonomous decision making whereby educators have a repertoire of pedagogical strategies, and accountability in that the economic educator must excel in knowledge of both economics and how to teach economics; research-based classroom practice, the utilization of current research about developmental learning levels, age appropriateness and modeling theory as it relates to economic education; and equity in education, an emphasis on high standards of learning for all students, recognition of changing demographics and the consequent need to accumulate more information on the learning styles and proclivities of at-risk populations.

Conclusions

"True reform, as we see it, is more than just commitment or ideology. It is the willingness to alter, enhance, and reform the system from within in the hopes of improving the conditions and outcomes for all involved. We believe that as economic educators we have the vision, the resources, and the energy to conceptualize, plan, and activate educational reform nationwide and, in so doing, increase the economic literacy of our citizens" (Kourilsky and Quaranta). Will agricultural economists be part of the cast of collaborative players?

References

Bach, G. L. "Economics in the High Schools: The Responsibility of the Profession." *Amer. Econ. Rev.* 51(1961):579–86.

Buckles, Stephen. "Visions for the Future." *Effective Economic Education in the Schools*. New York: JCEE, 1991.

Doering, Otto. "Adapting to New Roles and New Clientele: How Do We Get There from Here?" Challenges for Extension Economists in the 1990s. Proced. of the AAEA Extension Conference, Vancouver, B.C., Canada, 4 Aug. 1990.

Gilliard, June V. "Future Requirements for Programs and Materials." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Gilliard, June V., J. Caldwell, B. R. Dalgaard, R. J. Highsmith, R. Reinke, and M. Watts. *Economics: What and When (Scope and Sequence Guidelines, K–12)*. New York: Joint Council on Economic Education, 1988.

Hermanowicz, Henry J. "Recommendations for Teacher Education in the Context of the Reform Movement." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Highsmith, R. J. *A Survey of State Mandates for Economics Instruction, 1989*. New York and Washington, DC: JCEE and NFIB Found. 1989.

Joint Council on Economic Education. *Directory: Affiliated Councils and Centers*. New York, 1991.

——. *JCEE 1988–1989 Annual Report*. New York, 1989.

Kohl, David M., L. A. Shabman, and H. H. Stoevener. "Agricultural Transition: Implications for Agricultural Economics Extension in the Southeast." Paper presented at the SAEA Meetings, Nashville TN, 2 Feb. 1987.

Kourilsky, Marilyn. "The Kinder-Economy: A Case Study of Kindergarten Pupils' Acquisition of Economic Concepts." *Elementary School J*. 3(1977):182–91.

Kourilsky, Marilyn, and E. Graff. "Children's Use of Cost-Benefit Analysis: Developmental or Non-Existent." Paper presented at the annual meeting of the Amer. Educ. Res. Assoc., Chicago, 1985.

Kourilsky, Marilyn, and L. Quaranta. "Economic Education and Educational Reform: Partners for an Economically Literate Future." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Lewis, Ben W. "Economic Understanding: Why and What." *Amer. Econ. Rev.* 47(1957):653–70.

Marlin, James W., and G. C. Durden. "An Analysis of Contributions and Contributors in Economic Education." University of Nebraska, Lincoln, 1991.

Miller, Steven. "The Case for Economic Education in the

School Curriculum." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

National Council for Social Studies (NCSS). "In Search of Scope and Sequence for Social Studies." *Soc. Stud. Educ.* 48(1984):250.

National Research Council (NRC), Committee on Agr. Educ. in Secondary Schools and Board on Agr. *Understanding Agriculture: New Directions for Education*. Washington, DC: National Academy Press, 1988.

Saunders, Phillip. *The Historical Evolution of the American Economic Association's Position on Economic Education*. Indiana University Work. Pap. in Econ. No. 91-012, 1991.

Saunders, Phillip, G. L. Bach, J. D. Calderwood, and W. L. Hansen. *A Framework for Teaching The Basic Concepts*, 2nd ed. New York: Joint Council on Economic Education, 1984.

Schug, Mark C. "The Development of Students Economic Thought: Implications for Instruction." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Schug, Mark C., and D. Wentworth. "What Does Economics Contribute to Social Studies?" *Forum* (Newsletter of the National Association of Economic Educators) 3(1990)1–13.

Schuh, G. Edward. "Emerging Challenges for Extension in the 1990s. *Challenges for Extension Economists in the 1990s*. Proc. of AAEA Extens. Conference, Vancouver, B.C., 4 Aug. 1990.

Sharradan, M. "School Dropouts in Perspective. *Education Forum* (1986)15–31.

Soper, John C., and W. B. Walstad. "Economic Knowledge in Junior High and Elementary Schools." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Walstad, William B., and J. C. Soper. "Economic Literacy in Senior High Schools." *Effective Economic Education in the Schools*. New York: Joint Council on Economic Education, 1991.

Walstad, William B., and J. C. Soper, eds. *Effective Economic Education in the Schools*. New York and Washington DC: Joint Council on Economic Education and Nat. Educ. Assoc., 1991.

Education in Economics: Evidence on Determinants of Effectiveness

Robert J. Highsmith and William J. Baumol

This paper reports the results of a series of seventeen studies based on extensive new data and carried out independently by twenty-two investigators; the studies shed new light on the influences affecting the degree of success in the teaching of economics at the pre-college level. The significance of the results goes well beyond economic education, for it offers some suggestive evidence pertinent to such critical issues as the relative success of different teaching arrangements in improving the general educational performance of students from disadvantaged minority groups relative to the student population as a whole. The study also offers insights on the pertinence of teacher education, indicating, for example, that an additional undergraduate course in economics taken by the teacher contributes substantially more to the performance in economics by the student than either an additional graduate course or an additional year of experience in teaching the subject. These and the other results that emerged from the studies are reported in detail in this paper. The main surprise is that there are so few surprises; that, by and large, the data are consistent in supporting what can be described as the common-sense expectations and prior research in the area.

The studies themselves emerged out of two associated endeavors. The first was the construction of an extensive data base providing information on a nationwide sample of high school students, their teachers, their schools, and their school districts. The sample consisted of 3,266 students, 121 teachers, 70 schools, and 61 school districts; the survey was conducted by written questionnaire. The survey gathered data on the pupil's family (parents' education, occupation, etc.), ethnic affiliation, future educational plans, study practices, and attitudes toward economics. Information about the teachers included education, teaching experience, attitudes toward teaching of economics, and other related material. From the schools, the study obtained information on the socioeconomic composition of the student body, type of location (urban, suburban, etc.) and the regulations on study of economics by pupils (optional, required). The data were collected in a way that permitted comparison of student answers to the questionnaire with their performance on the standardized Test of Economic Literacy (TEL), the educational attainment and experience of their teachers, and so forth.

The second activity that underlies the results reported here was a program of training in econometrics and associated research methods that was provided to a group of forty-three young economists, faculty members at institutions of higher education throughout the United States, who were interested in conducting research related to economic education. The attendees at these sessions each undertook to carry out a piece of research during the year that followed, using the new data base described in the preceding paragraph. The research was carried out at the participants' home institutions. The results that emerged from these pieces of research constitute the basis of this article. Obviously, the authors of this survey owe much more than the usual debt to these young researchers.

Because the material that follows is a report on well over a dozen studies conducted largely in isolation from one another, it is impossible to provide a single general description that fits them all. As is to be expected, they differed in the specification of their estimation equations, in the list of both dependent and independent variables considered, and in their statistical estimation procedures. As the discussion proceeds, the list of variables utilized will become clearer. Generally, the estimation methods involved multivariate analysis and fell into two broad categories: ordinary least squares (OLS) computations and probit calculations. Because the interpretation of the resulting estimates is so different, the OLS and the probit calculations

Robert J. Highsmith is Vice-President for Programs and Research, Joint Council on Economic Education; William J. Baumol is a professor of economics at Princeton and New York Universities.

This research was supported in part by the J. Howard Pew Freedom Trust.

cannot simply be merged. Still, it is possible to characterize their general implications in verbal, qualitative terms. It is to this we next proceed.

However, as a last preliminary observation, it should be noted that the substantial number of quasi-independent estimate replications should be considered as a source of strength to the discussion here. The sensitivity of econometric results to changes in model specification and other variations is well known. Consequently, often one has confidence in the reliability of an econometric result when it is confirmed by other studies independently conducted. Here, because all of the studies have used the same data base, the independence of the results is somewhat attenuated. Still, each is sufficiently different from the others in conception, in structure, and in portions of the data utilized that they do indeed serve as an effective means to check upon one another's results.

Teacher Background and the Performance of Pupils

We begin our report with the contribution to the performance of the pupils on the standardized Test of Economic Literacy (TEL) that was offered by the experience and training in economics of their teachers.

College Courses in Economics Taken by Teachers

The results were consistent with those of previous studies, indicating that students perform better on tests of economic understanding when their teachers have received additional training in economic content and pedagogy, but the influence is relatively small. Although one researcher found "number of hours earned in undergraduate economics" was insignificant as a predictor of performance on the TEL (Beron), two others using OLS techniques found that, on average, each three-semester-hour course taken by a teacher is associated with small increases in test performance ranging from .60 to .93 correct answers (Grimes and Register, Heath), and a third, using the probit technique (Wetzel), also found a significant positive relationship. Graduate courses matter, too, although less so, with the contribution of each course to students' TEL scores ranging from .03 to .27 questions (Blais and Greenwood). Researchers who combined both undergraduate and graduate training discovered that their combined influence varied from an educationally negligible but statistically significant effect to an average of .57 questions for each course taken (Marlin, Wetzel, Foeller and Cobb, Loviscek and Crowley).

One researcher also inquired into the effects of teacher training on a student's chances of scoring above average on the TEL and on the level of teachers' enjoyment from teaching economics. Investigation of this relationship revealed that the probability that students will score higher than average on the TEL rises by a small amount as the number of undergraduate and graduate-level courses rises. Modest increases also occur in the probability that teachers enjoy teaching economics when they take more courses and experience more in-service training in economics (Foeller and Cobb).

It would appear that each undergraduate course taken by teachers has, on average, about three times more impact than graduate courses on the economic understanding of their students (Blais and Greenwood, Beron, Grimes and Register, Heath). This is not surprising because most "graduate" courses are offered to teachers in-service, usually after school. Some class time is used for pedagogy and to review teaching materials, taking time away from the coverage of content. Moreover, such courses do not run as long as standard undergraduate courses.

We turn next from the teachers' training to the length of their overall teaching experience, which on the whole, seems (perhaps surprisingly) to reduce the effectiveness of instruction.

Years of Experience of Teachers

Of the studies, one found teachers' general experience in all academic subjects to have no significant influence on students (Marlin), but four others found the influence was significant and negative, ranging from −.24 for each year taught to a small negative number (Heath, Grimes and Register, Foeller and Cobb, Rhine). Two studies found that total years of experience in teaching economics has a significant influence on students' economic understanding (Grimes and Register, Marlin), but they disagree as to whether the effect is positive (.13) or negative (−.34). Finally, a negligible and negative probability is associated with total years of teaching experience and teachers' enjoyment from teaching, and a considerably larger negative probability with total years teaching of economics and teachers' enjoyment. (Foeller and Cobb). It appears the

longer they teach economics the less teachers like doing so.

The first result can perhaps be explained by the fact that teachers with more general experience are further removed from direct contact with the study of economics than their less-experienced colleagues. This seems to support the hypothesis that teachers' undergraduate training in economics appears to have the greatest effect on their ability to increase the economic understanding of their students. Greater experience apparently is not sufficient to offset the erosion in their knowledge as teachers age. Of course, it is also possible that more-experienced teachers studied less economics than their less-experienced colleagues and that "years of teaching" is really a proxy for less training. Full exploration of that possibility must await future study. The other results suggest that protracted teaching of economics reduces the excitement of the task, and this may reflect itself in the effectiveness with which it is carried out.

Higher Education of Teachers

One expects that the earning of higher degrees (M.A. or Ph.D.) by teachers will be associated with increments in students' economic understanding either because teachers take more economics courses as part of the degree program or because the additional degrees are a proxy for greater motivation of the teachers who earn them. Alternatively, one might reasonably expect, given the fact that little additional coursework in economics is typically involved, that no increase in students' economic understanding results from accumulation of additional degrees by their teachers.

One researcher found evidence to support the first of these conflicting interpretations. When teachers earn degrees beyond bachelor's degrees, their students experience increases on the TEL averaging 2.75 correct answers (Lopus).

Sex of the Teacher

Several of the studies also examined the implications of the teachers' sex upon the performance of the students. Two investigators found that the students of female teachers had significantly higher TEL scores (2.53 to 3.83 questions) than students of male teachers (Marlin, Heath). This may at first be surprising, given the consistently superior performance of male undergraduates on multiple-choice tests in economics. However, there is evidence that women in college perform better on essay tests in economics, and this difference may perhaps indicate something about the depth of their understanding once they become teachers (Lumsden and Scott). Two studies also examined sex differences in the reported enjoyment of the teaching of economics, but the differences were found to be significant only in one (Foeller and Cobb, Marlin).

Teachers' Enjoyment of Economics

A priori, one would also expect that teachers who report that they like to teach economics are more effective than less-enthusiastic teachers in imparting economic understanding to students. Our results support this expectation, with the range of positive effects from teachers' enthusiasm varying from 3.37 to 5.43 questions on the TEL (Lopus, Marlin, Blais and Greenwood, Grimes and Register).

Class Size and Other Educational Choices

We turn next to the effects upon student performance of educational decisions—class size, homework assignments, required rather than voluntary study of economics, and the availability of specially designed economics teaching materials.

Class and School Size

We found modest support for the hypothesis that larger classes diminish learning. As the number of students in an economics class increases, on average, students perform less well on the TEL by .08 questions per student (Lopus), implying that each addition (beyond some critical minimum level, presumably) of twelve students to a class causes average performance of all students to decrease by one question.

The size of school, in contrast, is positively associated with average student performance in states where the teaching of economics is required, and the coefficients indicate that the addition of 500 students (again beyond some minimum level and up to some maximum level, presumably) causes each student's TEL score to increase by 1 question (Rhine).

These results seem plausible. Beyond some

optimal level, one may expect that additional students in a class will detract from the average productivity of the teacher. And combined, both results suggest, assuming they prove upon further investigation to be robust, that most classes are too large for optimal teaching of economics while most schools may be smaller than optimal, measured in terms of pure output, without balancing off the associated costs.

Mandatory Study of Economics

If students are all required to study economics, this may increase their exposure to economics, improving their exam grades. On the other hand, this may be imposed on reluctant school districts or unprepared teachers or unwilling students, resulting in decreases in students' understanding. Hence, it is not easy to predict the direction of the effect of required study of economics. For similar reasons, it is difficult to predict the effects on the probability that teachers will enjoy teaching economics and that students will want to take additional economics courses.

In one investigation, the data indicated that such a rule is associated with decreases in average performance of students, cutting TEL score by 2.96 questions (Beron). Two other researchers produced conflicting results on the effect of mandates upon the probability that teachers will enjoy teaching economics, with one finding a strongly negative effect and the other a strongly positive effect (Marlin, Foeller and Cobb). Another study found no significant relationship between mandates to teach economics and the probability that students will want to take another economics course (Peterson).

Amount of Time Spent on Homework

Several researchers found that each additional hour spent on homework was associated, on average, with a TEL score's increase from .66 to 1.12 questions (Marlin, Rhine). Efforts to assess by how much selected amounts of time spent on homework influence grade point averages indicate that one-half hour per week on homework is associated with a .16 increase in GPA, one hour with .20 to .27, two hours with .31 to .42, and more than two hours with a .55 increase in GPA (Lillydahl).

Participation of the School in Programs to Strengthen the Teaching of Economics

Programs have been designed with some care to increase the effectiveness of the teaching of economics in secondary and primary schools. The Joint Council on Economic Education (JCEE) has designed and disseminated a number of them.

The Developmental Economic Education Program (DEEP) is perhaps the most fully developed of such programs. Through DEEP, school systems build quality economic education programs. As a result, students are equipped with powerful knowledge and skills that enable them to function effectively, wisely, and efficiently in a complex world. To accomplish this, DEEP school systems extend their own resources by working with their communities and with local affiliates of the national JCEE network. DEEP participation reflects the commitment of a school district to use quality instructional materials at key points in the curriculum, to prepare teachers to incorporate economics content into their instruction, and to evaluate their progress.

The degree of success of DEEP in promoting student understanding of economics has been studied extensively in previous investigations, but its role in shaping teacher and student attitudes about economics was examined for the first time in the studies reported here. As in previous research, it was found that DEEP contributes understanding of economics by students in an amount ranging on average from slightly more than 2 to 4.54 questions on the TEL (Blais and Greenwood, Beron, Heath, Peterson, Rhine, Vaughan and Fuller). One study, upon disaggregating students into males and females, discovered that being male is not significantly associated with better TEL scores in DEEP schools but being females is, by 6.0 questions. DEEP also contributes strongly to the probability that teachers enjoy teaching economics (Foeller and Cobb) but negatively to the probability that students are interested in taking another economics course (Beron).

There are no surprises in these results. DEEP is designed to support teachers, schools, and school districts by providing services (curriculum assistance, teacher training, and instructional materials) that enhance teachers' effectiveness. The data support the efficacy of these activities. The weak negative relation between DEEP and students' interest in taking additional economics courses seems associated with the orientation of DEEP toward making it possible

for teachers to teach more effectively, rather than motivating students to go on in the field.

Influence of Family Environment

Another set of variables that has, deservedly, attracted considerable attention relates to the effects of the student's family circumstances upon learning of economics.

Parents' Education

The studies that examine the effects of their parents' education on students' performance produced broadly similar results, although the influence on TEL scores varied, depending on the proxy used and the sex of the parent. Whereas the highest level of schooling achieved by fathers was an insignificant influence on the performance of students, a .64 improvement in average TEL scores resulted from each increment in the education of mothers (Marlin). When fathers were college graduates, their children answered correctly, in one study, 2.55 questions more on the TEL than did other students (Grimes and Register) but about 1.50 questions fewer in a second (Vaughan); whether or not mothers were college graduates proved insignificant in one study (Grimes and Register) and worth about 2.25 questions in a second study (Vaughan).

A priori, parents' education would seem a strong predictor of student performance on the TEL, with parents who have succeeded in school passing on to their children the skills and values which account for their success. The results here are consistent more frequently than not with that hypothesis. However, the failure of both mothers' and fathers' education to achieve significance in at least one of the proxies, the lack of consistency in the results by sex among proxies, and the negative coefficient reported above in one study for "father is a college graduate" suggest that caution should be exercised in drawing implications from these results.

Occupation of Parents

Surprisingly, the professional status of their parents was revealed in these studies to be at best a modest contributor to students' economic understanding. One study, using several different specifications of the problem, found that no significant rise in test score occurs when students reside in homes where either parent is a professional (Lillydahl). Another study found, in contrast, that when disaggregating parents into two groups, i.e., those in which the mother is a professional and those in which the father is, the professional status of both parents is associated with modest but significant increments to students' performance, equal to 1.7 questions in the case where the father is a professional and 1.3 when the mother is (Vaughan and Fuller).

Broken or Intact Families

Living with both parents might be expected, a priori, to provide students with a more stable home environment, more supervision, more attention to students' school assignments, and result in higher grades. Several attempts by one researcher to find support for this hypothesis were disappointing, yielding no significant influence in three attempts and a modest positive effect (.13 questions on the TEL) that is statistically significant but educationally insignificant in a fourth attempt (Lillydahl).

English Spoken at Home

Speaking the same language at home as at school removes an impediment to learning and, as a result, might on the one hand be expected to be associated with higher TEL scores and grade point averages. On the other hand, a person challenged by two different languages and/or motivated to do well might actually surpass the performance of students facing fewer obstacles.

Given these conflicting possibilities, it is rather surprising that speaking English at home was found by one researcher to increase TEL scores strongly by 3.15 points in one specification of the problem but to yield no significant difference in another formulation (Lillydahl).

Family Interest in Homework

Family interest in homework might, for obvious reasons, be expected to improve student performance if by doing their homework the students acquire valid information or feel encouraged by the demonstration of willingness to help. Still, if their parents impart misinformation, or their

participation exacerbates parent-child conflicts, family interest in homework can become an impediment to the student.

Three investigators found consistently negative effects to result from increases in family interest in homework, ranging from −.58 to −2.17 questions on the TEL (Rhine, Marlin, Grimes and Register). Marlin also found that the probability was insignificant that greater interest by families in their childrens' homework contributed positively to the enjoyment teachers get from teaching economics (Marlin).

The Effects of Student Characteristics

We come, finally, to the relatively large number of variables characterizing the students themselves that were investigated in the studies.

The evidence is quite clear that being a male in high school is associated with higher scores on the TEL and with the decision to take economics, and being a female is not.

Five investigators found that the TEL scores of males are anywhere from 1.24 to 2.84 questions above the average (Lopus, Rhine, Marlin, Heath, Beron), whereas only one found this to be an insignificant influence (Grimes and Register). Two researchers found that female students' TEL scores ranged from 1.67 to 3.0 questions below the average (Peterson, Vaughan). When students are male, the probability that they will have taken economics is strongly positive (Heath); when students are female, the probability that they will take another economics course is not significant (Beron).

Several interesting covariates were investigated by one researcher to determine how the student's sex and other independent variables of interest correlate simultaneously with changes in performance in economics. All females who take economics perform better by about 3 questions than females who do not. Hispanic females who take economics do better by about 1.6 questions. However, urban females do worse, on average, by about 3.2 questions (Vaughan and Fuller).

These results are consistent with our expectations, reflecting the usual evidence about the cultural forces at work on different types of students and the influence of the location of a school.

Student's Race

Studies of the association of race with performance on the TEL, and on students' interest in taking more economics, have revealed results broadly similar to those in other fields. That is, being white is associated with increases in TEL scores ranging from 1.82 to 3.73 questions (Lopus, Grimes and Register, Rhine), being African-American with decreases ranging from 2.60 to 3.91 questions (Loviscek, Peterson, Vaughan and Fuller, Beron), and being Hispanic with a decrease of 4.4 questions (Rhine). Surprisingly, given the results just reported, one researcher found that being black was associated with a positive probability that the student will want to take another economics course (Beron), perhaps because the perceived returns from the study of economics are considered greater by African-Americans.

Finally, one investigator disaggregated black students by sex and discovered that there is no significant difference in TEL scores of black females, but there is a significant negative difference for black males, amounting to 2.60 fewer correctly answered TEL questions (Loviscek and Crowley).

Student Performance in Other Subjects

Broadly speaking, grade point average (GPA) is a strong predictor of performance on the Test of Economic Literacy. Seven different investigators found that as GPA increases by 1 point, the average number of questions correctly answered on the TEL increases anywhere from 1.08 to 4.56 (Marlin, Vaughan and Fuller, Grimes and Register, Lopus, Heath, Lillydahl, Blais and Greenwood). After disaggregating GPA into five categories, one researcher found that students whose GPA is below the C to B range tend to lose 2.09 points on the TEL whereas students with grades in the C to B range average 2.47 more correctly answered questions. B students achieve 5.90 questions, B to A students 6.92 questions and A students 9.66 questions, more than they would have done otherwise (Peterson).

One investigator also found that higher GPA's increase the probability that students will take an economics course (Heath). Given the reputation of economics as a challenging course, this is not surprising.

Student's SAT Scores

Like most previous investigators, researchers in the studies reported here found a consistent, positive, and statistically significant correlation

of TEL scores with the combined verbal and mathematics scores on the SAT (Beron, Clark, Grimes and Register, Loviscek and Crowley, Rhine). Extrapolating from the results, each thirty additional points on the SAT are associated with a one question improvement on the TEL.

Increases on combined SAT scores are also associated with a positive probability that students will take another economics course (Beron), as one might expect, and with a slight positive probability that the school district in which the students are enrolled is in DEEP (Loviscek and Crowley).

School Absences

One researcher investigated whether school attendance had any bearing on performance in economics and on school performance in general. Students who had no absences in a month were found to perform on average better by 1.52 questions on the TEL compared with students absent more than two days (Lillydahl). Students with no absences were found to have higher grades ranging from .20 to .33 points in all their courses compared with their peers who were absent more often.

These results, like most of the others related to students, accord with, rather than contradict, common sense. One would expect, a priori, that better attendance would cause both test scores and GPA's to increase.

Knowledge of Other Subjects

Several investigators inquired into the contribution of selected high school courses to student performance in economics. Not surprisingly, an economics course contributed the most, adding 3.37 questions to students' TEL scores (Lillydahl). Each social science course was found by another researcher to add 1.90 questions (Vaughan and Fuller). Given the fact that high school courses in economics focus on geometric rather than algebraic representations of economic models, it is not surprising that one researcher found that geometry contributes a little more than 2 questions (Vaughan and Fuller) whereas algebra made no significant contribution (Heath). Having taken an algebra course was found by Heath, however, to contribute a strong positive probability that students would take an economics course (Heath). Finally, having taken a business course was associated with a positive probability that students would take an economics course (Heath). However, taking a business course earlier was associated with a TEL score that was smaller by 1 question than that achieved by students who had never taken one (Vaughan and Fuller).

Evaluative Comments

The studies reported here leave the reader with considerable admiration for the competance of the younger researchers who carried them out. In terms of substantive import, the results largely speak for themselves. Rather than singling any of them out for recapitulation here, it seems more germane to note their general implication, that in the field of economic education, and perhaps in other educational arenas as well, common sense seems to be a fairly reliable guide. Most of the patterns that emerged are those that one might have expected and those that people who work in the area seem widely to believe to prevail.

The results reported here also suggest that much remains to be done in analyzing the rich, new body of data that was used here. Clearly, much needs to be done by way of estimation of interactive effects—the coefficients of terms that involve the interaction of several variables. Some very urgent social issues require this sort of extension of the investigation. An example will bring out the point. The study has examined the consequences for student performance of various teaching rules and practices, and it has also documented once again the preponderantly poorer educational performance of African-American and Hispanic students. But the conjunction of these two types of information surely raises the issue of their interaction. Which of the teaching practices that has been shown to be beneficial also offers any promise of reducing the gap in performance between students from these minority groups and the remainder of the student body? Questions such as this are obviously of critical importance, and a study of interactive relationships is an obvious next step in attempting to cast light upon the matter.

References

Beron, Kurt. "Joint Determination of Current Classroom Performance and Additional Economics Classes: A Binary/Continuous Model." New York: Joint Council on Economic Education, 1989.

Blais, Jeffrey, and Daphne T. Greenwood. "The Effects of Teacher, Student, and School Characteristics on Student Achievement in Economics." New York: Joint Council on Economic Education, 1989.

Clark, James E. "Using a Translog Production Function to Analyze Input Use in High School Economics Classes." New York: Joint Council on Economic Education, 1989.

Foeller, William H., and Steven L. Cobb. "An Organizational Behavior Analysis of Teacher Attitudes About Teaching High School Economics." New York: Joint Council on Economic Education, 1989.

Grimes, Paul W., and Charles A. Register. "Teachers' Unions and Student Achievement in High School Economics." New York: Joint Council on Economic Education, 1989.

Heath, Julia A. "An Econometric Model of the Role of Gender in Economic Education." New York: Joint Council on Economic Education, 1989.

Highsmith, Robert J. "The Research Core of Economic Education." *Theory into Practice* 3(1987):216–23.

Leet, Don R. "Why Do School Districts Enroll in the DEEP Program? A Probit Using the NAEE Database." New York: Joint Council on Economic Education, 1989.

Lillydahl, Jane H. "Academic Achievement and Part-time Employment of High School Students." New York: Joint Council on Economic Education, 1989.

Lopus, Jane S. "Do Additional Expenditures Increase Achievement in the High School Economics Class?" New York: Joint Council on Economic Education, 1989.

Loviscek, Anthony L., and Frederick D. Crowley. "Knowledge in Economics: The Impact of the Developmental Economic Education Program by Gender." New York: Joint Council on Economic Education, 1988.

Lumsden, Keith G., and Alex Scott, "The Economics Student Reexamined: Male-Female Differences in Comprehension." *J. Econ. Educ.* 3(1987):365–76.

Marlin, James W., Jr. "State Mandated Economic Education, Teacher Attitudes, and Student Learning." New York: Joint Council on Economic Education, 1988.

Peterson, Norris A. "Self-Selection in the NAEE Database." New York: Joint Council on Economic Education, 1989.

Rhine, Sherrie L. W. "The Influence from State Mandates on Student Performance: A Database Comparison." New York: Joint Council on Economic Education, 1989.

Vaughan, Michael B., and Dan A. Fuller. "Gender Differences in Economic Literacy: The Influence of Race and Urban Setting." New York: Joint Council on Economic Education, 1989.

Wetzel, James N. "Doing Well on the TEL: High Achievement in High School Economics." New York: Joint Council on Economic Education, 1989.

Toward Increased AAEA Involvement in Economics Education: Discussion

Marc A. Johnson

Education in choice making can help young people prepare themselves for the inevitable decisions they will make in life. Education on economic systems can help them understand contemporary developments in history, politics, and industry. Agricultural economists are associated with educational institutions which have access to youth, e.g., 4-H, FFA and Ag in the Classroom. Our association leadership is making a useful effort to explore effective means of enhanced involvement of agricultural economists with economic education for youth. The two papers in this session have different purposes and will be discussed successively.

Highsmith presents a summary of seventeen student research papers using a similar data set. Model specifications and results are not presented; a critique of the method by which conclusions have been drawn is not attempted. Educational significance of reported results is difficult to judge because the dependent variable in each study is number of questions answered correctly on the TEL. Not knowing how many questions are on this test makes it difficult to know whether a two-question improvement is important.[1] In this discussion, some results are highlighted and some alternative explanations are offered.

First, Highsmith concludes that additional college courses in economics for high school economics teachers have a small but positive effect on student performance and that undergraduate courses have a greater effect than graduate courses. These effects are attributed to instructional procedures. Alternatively, the principle of diminishing returns may explain these observations. For a teacher producing a high school level economics course, college economics training may have steeply diminishing returns. If a teacher is fully qualified to take a graduate course, he/she has much economics background and the marginal effect of a graduate course to build on high school level concepts might be negligible.

A second, disturbing result is that the more experience a teacher has in general and in the teaching of economics, the poorer their students will perform. There is a natural affinity of young students for young teachers. Beyond this, these results imply that school districts and teachers underinvest in human capital maintenance. This includes investments in knowledge, teaching technique, and excitement. A program to take teachers with seven or more years of economics teaching experience to Europe to learn about the GATT might bring new excitement in the teacher and, thereby, in the student.

A corollary result is that teacher's interest and enthusiasm for economics yields more effect on student performance than more teacher training and experience. Thus, teacher training could use a healthy dose of showing relevance of economics as a useful tool for addressing current issues, to build enthusiasm for the topic.

Highsmith's section on "class size and other educational choices" shows results which mirror those of other recent studies. School district financial outlays, class size, and regulations for mandatory economics instruction have little effect on student performance. What does affect student learning is direct teacher training and time spent on homework. While falling national test scores have been blamed on lack of funds, there is no substitute for setting performance expectations which require diligence on the part of the student.

The objectivity of the student researchers is called to question in the example of measuring the effect on test performance of the student coming from a broken home. Highsmith concludes that "several attempts by one researcher

The author is a professor and head, Department of Agricultural Economics, Kansas State University.

[1] The number of questions on the Test of Economic Literacy (TEL) was later found to be 46. A one-question improvement represents about a 2% increase in economic knowledge.

to find support for this hypothesis were disappointing." One could actually be happy to learn that the null hypothesis could not be rejected, suggesting that divorce does not destroy a child's ability to learn economics.

Finally, the effect of taking economics courses in high school appears educationally negligible. On average, a student who took an economics course scored 3.37 correct answers more than a student who did not take such a course. Women with an economics course scored 3 more correct answers than the average of all women. Urban women with an economics course were more confused than if they had not been introduced to economics because they scored 3.2 less correct answers than the average urban woman.

Highsmith provides an interesting group of results. Teacher training in economics has positive effects on teacher enthusiasm and student performance. Teacher enthusiasm and homework time are the most important influences on student learning of economics. Agricultural economics courses tend to have smaller class sizes and more attention to applications of economics to real-world events. Agricultural economics could contribute positively to teacher training and teacher enthusiasm.

Reda-Wilson presents a passionate argument for economic and agricultural education in schools and affiliation of AAEA with the Joint Council on Economic Education (JCEE). The necessity for economic and agricultural education are shown to spring from the same origin. However, the extension of the rationale for economic education to agricultural education is not compelling. In a decentralized economy, consumers need information on product availability and price to make rational decisions; knowledge of industry structure and policy are incidental. Economic education provides the principles of decision making and markets. Agricultural education does not involve basic principles.

Reda-Wilson recommends that agricultural economics departments shift resources to economic education. Currently, departments are free to invest resources in economic education and have not chosen to do so in a significant magnitude. Proponents of economic education will have to show the demand for this topic, to coalesce the interests to design activities and to demonstrate cost effective means to implement economic education.

In March 1991, the Farm Foundation supported a meeting of various groups with interest in youth education, including 4-H, vocational agriculture, Ag in the Classroom, and the Joint Council on Economic Education. Each group has a distinct objective and each has developed a delivery mechanism with institutional affiliations. These groups must be interested in some facet of agricultural economics education if departments are to develop cost-effective youth education programs. Either these organizations must adopt some common objectives or departments must implement strategies for youth education delivery through one or more of the existing organizations. An association affiliation with JCEE would be a useful step if delivery through public schools is determined to be the best mechanism.

Contaminated Collateral and Lender Liability: CERCLA and the New Age Banker

Michael T. Olexa

Enacted in December of 1980, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or the Act) authorizes the federal government to clean up inactive hazardous waste sites that threaten human health or the environment (42 U.S.C. 9601–9675, 1982 and Supp. V 1987). CERCLA, also known as "Superfund," provides a fund for cleanup of contaminated sites when no other parties are able to conduct the cleanup. This enormous reserve of money is replenished from federal funds, taxes on certain chemicals and petroleum, litigation settlements with responsible parties, and recovery of fines. CERCLA empowers the Environmental Protection Agency (EPA or the Agency) to recover the cleanup costs from those parties responsible for the contamination, if they can be identified, with little or no costs to the American taxpayer.

Because of the need for reauthorization, and calls for legislative clarification of what has been cited as poorly drafted legislation. (*United States* v. *Northeastern Pharmaceutical & Chemical Co.*, 579 F. Supp. 823, 839, W.D. Mo. 1984). CERCLA was amended in October of 1986 by the Superfund Amendments and Reauthorization Act, also known as SARA (Pub. L. No. 99-499, 100 Stat. 1613–1782, 1986; codified throughout 42 U.S.C. Sections 9601–75, 1982 & Supp. V 1987). However, these amendments have proved to be inadequate because of inconsistent judicial interpretation and implementation of the Act's stringent provisions regarding lender liability for contaminated collateral. As a result, lenders who are unsure of what constitutes risk-free lending activities under CERCLA are again raising the call for further legislative reform.

What follows is a general overview of CERCLA provisions pertinent to lender liability, a review of several case law holdings which have added to lender confusion and heightened liability concerns, and a discussion of actions taken by lenders to avoid being cited under the Act for cleaning up contaminated properties.

Key CERCLA Provisions

As amended, CERCLA empowers the Environmental Protection Agency to identify and clean up inactive hazardous waste sites and to look to certain parties for reimbursement. Section 104 of the Act authorizes the EPA to act "whenever (A) any hazardous substance is released or there is a substantial threat of release into the environment, or (B) there is a release or substantial threat of release into the environment of any pollutant or contaminant that may present an imminent and substantial danger to the public health or welfare" (42 U.S.C. sec. 9604). The terms "hazardous substance" and "pollutant or contaminent" are defined differently for the purpose of response and do not include petroleum or petroleum products [42 U.S.C. sec. 9601(14)].

Several types of responses are authorized by CERCLA, including the following:

(*a*) shorter-term removal actions, to deal with spills and other emergencies which present imminent hazards and require immediate response, as well as nonemergencies which present a near-term threat. These actions are not dependent upon the site being on the National Priorities List (NPL), a master list of the "worst sites" created

---

Michael T. Olexa is an associate professor in the Food and Resource Economics Department, University of Florida.

This publication is designed to provide accurate and authoritative information regarding lender liability under CERCLA. The author is not engaged in rendering legal, accounting, or other professional advice, and the information contained herein should not be regarded, or relied upon, as a substitute for professional advice.

The author acknowledges the research assistance of Andrew Norris, a law student at the University of Florida School of Law.

to prioritize site cleanup [42 U.S.C. sec. 9605(a)(8)(B)]. And

(*b*) longer-term remedial responses designed to permanently solve the problems encountered at hazardous waste sites which are listed on the NPL. In addition to removal and remedial actions, the term response also includes enforcement actions against solvent potentially responsible parties (PRP's) for the cost of cleanup [42 U.S.C. sec. 9601(25)]. Primary responsibility for the cleanup of oil spills rests with the Coast Guard under the authority of the Clean Water Act (33 U.S.C. sec. 1321).

CERCLA recognizes several distinct classes of parties responsible for the cost of site cleanup. These potentially responsible parties include: (*a*) generators of waste; (*b*) transporters of the waste, including those who arrange for transportation; and (*c*) current or past owners or operators of the facility [42 U.S.C. sec. 9607(a)].

Liability for response costs is established when the EPA demonstrates that (*a*) the site is a "facility," defined by the Act as any area where a hazardous substance is located; (*b*) there has been a release or threatened release of some hazardous substance from the site; (*c*) the release or threatened release has caused the United States to incur response costs; and (*d*) the defendant is one of the persons designated as a party liable for costs. [See *United States* v. *Maryland Bank and Trust*, 632 F. Supp. 573, 576 (D. Md. 1986).]

Liability imposed under the Act is retroactive, strict, and joint and several. Because the Act is applied retroactively, an individual can be held responsible for contamination activities that occurred years before the enactment of the legislation. Strict liability or liability without fault is significant in that PRP's cited by EPA may be responsible for cleanup costs even though they played no role in generating or disposing of the hazardous waste. Joint and several liability enables the agency to pursue any single identifiable PRP as though s/he were fully responsible for the contamination. Penalties are severe, running the gauntlet from administrative fines to prison sentences. Providing false or misleading information or failing to report releases of hazardous substances is a criminal offense [42 U.S.C. sec. 9603(b), (c), (d)]. Because of these provisions and inconsistent interpretation by the courts of the Act's defenses against liability, CERCLA has become the acknowledged Darth Vader of environmental legislation [Annotation, "Recent Developments Under CERCLA: Toward a More Equitable Distribution of Liability." *E. Law Reporter* 17(1987):10197.]

Statutory Defenses

Depending upon the circumstances, individuals cited under CERCLA may offer as a defense that the release and damages were caused by (*a*) an act of God; (*b*) an act of war; and (*c*) the actions of a "non-contractual" third party [42 U.S.C. sec. 9607(b)]. Because use of either the God or war defense is at best remote, the third party defense offers the lender the best argument in avoiding agency action under CERCLA.

Third-party defense. Under the third party defense [42 U.S.C. sec. 9607(b)(3)], the defendant must establish by a preponderance of the evidence that (*a*) no contractual relationship existed "directly or indirectly" between the defendant and the third party, (*b*) a third party was the sole cause of the release or threatened release, and (*c*) the defendant showed all due care with respect to the hazardous substance and that precautions were taken against such occurrences [42 U.S.C. sec. 9607(b)(3)].

Prior to the passage of SARA, the third party defense offered little protection from cleanup liability for innocent parties acquiring property after it has been contaminated. Court decisions generally turned on a judicial interpretation of whether a deed or other document of property transfer constituted a contractual relationship between current and past owners of the contaminated property, with liability resulting from an affirmative finding. Courts often split on this issue.

Because of judicial uncertainty in application and interpretation of the Act, Congress responded with the SARA amendments. One key aspect of the SARA amendments was to clarify what constituted a "contractual relationship" in the original Act's third party defense in order to provide an unambiguous and equitable standard in raising the defense.[1] This congressional clarification of "contractual relationship" is now referred to as the innocent landowner defense (see footnote 1).

---

[1]Note "When a Security Becomes a Liability: Claims Against Lenders in Hazardous Waste Cleanup." *Hasting Law J.* 38(1987):1261, 1269.

Innocent landowners defense. In establishing this defense, the innocent landowner must at the time of acquisition: (*a*) have no reason to know of the property's contamination, and (*b*) have made "all appropriate inquiry" into the previous ownership and uses of the property consistent with good commercial or customary practices in an effort to minimize liability [42 U.S.C. sec. 9601(A)(i–iii)]. Factors considered by courts in determining whether "all appropriate inquiry" has been carried out include the defendant's special knowledge or experience, an imbalance between the purchase price and value of the property, commonly known or reasonably ascertainable information about the property, the obviousness of the presence of contamination, and the ability to detect the contamination by appropriate inspection [42 U.S.C. sec. 9601(35)(B)(Supp. V. 1987)]. With this effort to clarify the Act's ambiguous language, Congress has established a workable standard for determining due diligence in demonstrating "all appropriate inquiry."

While compliance with CERCLA's third party and closely tied innocent landowner defense may now limit an innocent landowner's exposure to cleanup liability, lenders still argue that it does not go far enough in detailing the specifics of what constitutes "all appropriate inquiry." Specifically, they contend that no guarantee of a liability-free transaction exists because a key element of the defense is still left to judicial scrutiny and interpretation by the courts of various jurisdictions.

Security interest exemption. In addition to the third-party and innocent landowner defenses, CERCLA also offers lenders some protection from liability exposure through the security interest exemption. CERCLA's security interest exemption provides that a lender holding an "indicia of ownership to protect his security interest in the facility" is exempt from liability as an "owner or operator" if s/he does not "participate in the management of the facility" (42 U.S.C. sec. 9601). While the exemption provides some liability protection, it has been narrowly interpreted by the courts.

United States v. *Mirabile* [15 *Environ. Law Rep.* 20994 (E.D.Pa. 1985)] served as one of the first cases where defendants argued for liability exemption under this defense. Here, the Environmental Protection Agency sued the current landowners, the Mirabiles, to recover cleanup costs for a previous owner's contamination. The Mirabiles in turn joined two banks as third-party defendants by alleging that as lenders to the previous owner, each contributed to the contamination.

The first bank, American, asserted as its primary defense that its foreclosure and related activities with the previous owner were carried out to protect its security interest in the property. Some of these management activities included involvement with marketing and sales strategies, as well as with employment benefits. American asserted that these did not constitute management of the facility and, as such, it was exempted from liability as the "owner and operator" of the facility and therefore not subject to cleanup costs. The court agreed. Mellon, the second bank, was not as fortunate. Because Mellon had placed its loan officer within the company to manage its daily business activities, it was found to have participated in the management of the facilities and, as such, was liable as an "owner and operator" under CERCLA. In holding Mellon potentially responsible for cleanup costs, the court adopted a "management participation" test which was widely accepted as the benchmark for deciding whether a mortgagee's conduct would qualify for "owner" liability under CERCLA or whether it would fall within the security interest exemption.

In *United States* v. *Maryland Bank and Trust* [632 F. Supp. 573 (D.Md. 1986)], the courts again addressed the security interest exemption. Here, the lender bank held a security interest on a 117-acre farm which had been used as a garbage dump. When the mortgagor was unable to continue payments, Maryland Bank purchased the property at a foreclosure sale. On discovery of the site's contamination with hazardous materials, EPA ordered the defendant bank to clean up the site. The bank refused, and the United States filed suit for the cost of cleanup.

One of Maryland Bank's defenses was that it was excluded as an "owner and operator" under the security interest exemption since it did not participate in the management of the facility and held indicia of ownership only to protect its security interest in the facility. The court disagreed. In its rejection of the defendant's argument, the court stated that the "security interest must exist at the time of cleanup," and added that Maryland Bank's security interest terminated at the foreclosure sale when "it ripened into full title." [632 F. Supp. 579 (D.Md. 1986).] Because the bank held legal title when cited by

the government, it was not entitled to the exemption. Some legal scholars speculate that the court's rationale may also have been influenced by the fact that, unlike American Bank in *Mirabile*, Maryland Bank had held the property for four years following its purchase, an indication that it purchased the property to protect its investment and not its security interest.[2] Nevertheless, the significant impact of the *Maryland* decision rests with the court's finding that lenders, even if not participating in the management activities of a borrower, may through foreclosure be held liable for cleanup costs under CERCLA. This rationale was followed in *Guidice* v. *BFG Electroplating Manufacturing Company, Inc.* [732 F. Supp. 556 (W.D.Pa 1989)], where the Court held the defendant lender, the National Bank of the Commonwealth, liable simply because it acquired title to the site after it had become contaminated.

In *United States* v. *Fleet Factors Corporation* [901 F. 2d 1550 (11th Cir. 1990), aff'g 724 F. Supp. 955 (S.D.Ga. 1989)], the 11th Circuit Court of Appeals addressed the exemption and significantly expanded the scope of lender liability. Here, the defendant lender, Fleet Factors, avoided foreclosure and retained a liquidator whose actions resulted in the release of hazardous wastes, including asbestos. The government also demonstrated that the defendant involved itself in the daily business activities of its insolvent borrower. Some of these activities included hiring, restricting shipping, and pricing during the period of its borrower's Chapter 11 status. In finding for the government, the 11th Circuit noted:

> . . . A secured creditor may incur . . . liability, without being an operator, by participating in the financial management of a facility to a degree indicating *a capacity to influence* the corporation's treatment of hazardous waste . . . a secured creditor will be liable if its involvement with the management of the facility is sufficiently broad to support the inference that it could affect hazardous waste disposal decisions if it so chose (901 F. 2d at 1557, 1558). (Italics added.)

The decision by the 11th Circuit in *Fleet Factors* holding a lender liable merely for having the "capacity to influence" business decisions of a debtor corporation set off shock waves and cries of alarm throughout the banking industry. The latest appellate court decision, that of the 9th Circuit Court in *In Re Bergsoe Metals Corporation* [910 F. 2d 668 (9th Cir. 1990)] has provided some reassurance to lenders, but it has also highlighted judicial uncertainty and contradictions regarding the security interest exemption. In *Bergsoe*, the 9th Circuit Court, while purporting to follow the 11th Circuit's ruling in *Fleet Factors*, specifically rejected liability for a lending institution strictly because of its "capacity to influence" a business decision. Instead, the 9th Circuit went back to the longstanding rationale provided in *Mirabile* and stated that a lender must exercise actual management authority before it is subject to owner liability under CERCLA [910 F. 2d 668 at 1787 (9th Cir. 1990)].

What's a Banker to Do?

With the costs of some cleanup responses far exceeding the value of the collateral, the existing judicial muddle regarding interpretation of CERCLA's provisions has created a significant amount of concern within the lending community. Because of this concern, bankers and other lenders have outright refused to lend if doubt exists as to the property's environmental quality. Some lenders have gone so far as to avoid foreclosure for fear of being strapped with the cost of cleanup. This in turn has spurred the industry to call for even further legislative and Agency regulatory reform and has forced the lending community to develop and implement environmentally sound risk management procedures as standard business practice.

Agency regulatory reform. Largely in response to the 11th Circuit's decision in *Fleet Factors*, the Environmental Protection Agency has proposed a draft rule clarifying actions that a lender can take to limit liability exposure when making or foreclosing on a loan.[3]

In addressing the security interest exemption, the Agency has set aside the "capacity to influence" standard of *Fleet Factors* and has instead required actual participation in the management of operational affairs of the facility before lia-

---

[2]See Bertz and Gillon. "Lender Liability Under CERCLA: In Search of a New Deep Pocket." *Banking Law J.* 11(1991):108. The Maryland court did not clearly distinguish between security interest and an investment. In dicta, the court's rationale appears to be largely based on the excessive period of time the defendants held the land following its acquisition.

[3]See "Credit or Following Regular Practice Exempt from Cleanup Liability, EPA Draft Rule Says." *Toxics Law Reporter* (BNA) 37(1991):1170.

bility is incurred. The draft rule sets out specific activities which the lender may engage in without being cited as a participant in the management of the facility. In policing its business transactions the lender may (*a*) require cleanup of the site before or during the course of the loan; (*b*) demand assurances that borrowers are complying with local, state, and federal laws and regulations; (*c*) inspect the facility; (*d*) provide financial advice to its debtor; or (*e*) carry out those steps necessary "to adequately police the debt or comply with applicable legal requirements" [5 *Toxics Law Reporter* (BNA) no. 37, at 1171 (20 Feb. 1991)].

The draft regulation also provides immunity protection for lenders that have foreclosed and held the contaminated properties for an extended period of time. According to the draft, property held in excess of six months may no longer be presumed to be held for investment purposes and may still be viewed as a security interest.[4] This would enable lenders who have foreclosed on contaminated properties to avoid owner liability as established in *Maryland Bank and Trust*. However, the burden of proof is still shouldered by the lender to demonstrate that the facility is being held to protect a security interest [5 *Toxics Law Reporter* (BNA) no. 37, at 1171–72 (20 Feb. 1991)].

The draft rule also addresses the innocent landowner defense. As proposed, the borrower or purchaser must investigate the previous ownership and uses of the property to qualify for the defense. While the proposed rule does not require environmental inspections, the agency does advise lenders to conduct environmental audits. Such an audit could serve to demonstrate the lender's environmental due diligence and good faith in complying with the intent of the rule, thus providing an excellent argument of entitlement for this and the other CERCLA defenses [5 *Toxics Law Reporter* (BNA) no. 37, at 1172 (20 Feb. 1991)].

The environmental audit. As early as the *Maryland* decision, the court warned lenders that: "Mortgagees . . . already have the means to protect themselves, by making prudent loans. Financial institutions are in a position to investigate and discover potential problems in their secured properties. For many lending institutions, such research is routine. CERCLA will not absolve them from responsibility for their mistakes of judgement" (Maryland Bank and Trust, 632 F. Supp. at 580).

This judicial rationale was not lost in the cases that followed or by the Environmental Protection Agency. Since this holding, the acceptable standard for prudent business practices necessitates site investigation and the exercise of care in avoiding the trap of contaminated collateral. While the audit does not guarantee a risk-free transaction, it can dramatically limit liability exposure under CERCLA by uncovering potential hazards.

The purpose of the audit is to gather information on past and present business practices, including full compliance with environmental regulations.[5] It is designed to identify and characterize environmental problems. At a minimum it should contain a historical evaluation of the facility, an examination of regulatory agencies for any liens or violations by the facility, and on- and off-site inspections. [See footnote 5, at 8 (March 1990).]

CERCLA down on the farm. Storage, use, and disposal of crop management materials and other hazardous substances are practices common to farm and ranch operations. As such, the prospect of site contamination remains high, especially with older operations. [See footnote 5, at 8 (March 1990).] CERCLA, however, does provide some liability protection for agricultural producers. The Act exempts the producer "for any response costs or damages resulting from the application of a pesticide product registered under the Federal Insecticide, Fungicide and Rodenticide Act" (FIFRA) [42 U.S.C. sec. 960(i)]. Specifically, the farm or ranch will not be considered a "Superfund site" or the owner held responsible for the cost of cleanup because pesticides applied in compliance with labeling are not considered hazardous substances.[6] This also includes the normal application of fertilizers. However, soil and ground and surface waters contaminated by the improper use, storage, or disposal of registered pesticides can result in CERCLA liability.

[4] See "EPA's Lender Liability Draft Rule in Final States, Legislation May Still Be Proposed." Hazardous Materials Control Research Institute, No. 5, p. 7, May 1991.

[5] See Missimer. "Environmental Audits of Agricultural Facilities and Properties." Proceedings of the Third Annual Agricultural Environmental Seminar of the Florida Fruit and Vegetable Association, March 1990, p. 4.

[6] See Wadley and Settle. "Statutory Regulation of Hazardous Chemicals on the Farm." *Agr. Law Update*, July 1989, p. 6.

Some of the more serious on-farm contamination problems involve mixing and loading sites. Cleanup costs here can be excessive. Thousands of these abandoned and contaminated sites are thought to exist throughout the United States, including the Southeast, the home of the 11th Circuit Court of Appeals. While farms and ranches have not yet been specifically targeted by the regulatory agencies, agriculture-related enterprises such as nurseries and golf courses have (see footnote 5, Missimer at 3). As a result, lending institutions are increasingly wary of becoming financially involved with farming operations and often require detailed environmental questionnaires and audits as a condition of farm purchase and production loans. Some have gone so far as to avoid foreclosure if the collateral is thought to be contaminated. Others have turned to such proactive approaches as providing seminars detailing CERCLA liability provisions and the necessity of engaging in environmentally safe production practices. CERCLA's fallout has placed bankers and other lenders in the position of environmental quality enforcers and educators.

Conclusion

CERCLA has been described as "a hastily drawn piece of compromise legislation, marred by vague terminology and deleted provisions." [*United States* v. *Northeastern Pharmaceutical & Chemical Co.*, 579 F. Supp. 823, 838 (W.D.Mo. 1984)]. Interpretations of its Draconian liability provisions have been largely left to the courts, who have had to struggle with little or no guidance from the Act's scant legislative history.[7] Because of this, judicial interpretation has caused confusion and concern within the lending industry. In response, bankers and other lenders have called for legislative reform and have initiated practices to limit their liability exposure. These practices have forced a variety of industries, including agriculture, to address the toxics issue and to develop environmentally friendly procedures as a prerequisite for doing business. Ironically, in this new age of environmental awareness, this vague, ambiguous, but necessary piece of legislation has placed the banker and other lenders at the forefront of environmental activism. The environmental legislation of the 1970s and 1980s has become the business reality of the 1990s.

[7] See Marzulla and Kappel. "Lender Liability Under the Comprehensive Environmental Response, Compensation, and Liability Act." *S. Carolina Law Rev.* 41(1990):705, 716.

Environmental Regulations and Agricultural Lending

Michael A. Mazzocco

U.S. commercial lenders were not at once responsive to the enactment of the Comprehensive Environmental Compensation and Liability Act of 1980 (CERCLA). Nor were they moved into action by the Superfund Amendments and Reauthorization Act of 1986 (SARA). However, the attention of many lenders was attracted by a series of court decisions which imposed upon lenders liability for the cost of cleaning environmentally damaged or contaminated property once belonging to their borrowers. (See Olexa, this issue, for a discussion of this series of cases.) Contemporaneously, countless additional state and federal environmental regulations have been enacted to control and/or repair environmental damage (Olexa 1990, Bock et al.).

The purpose of this paper is to describe lenders' responses to environmental regulations and case law, and the potential effect of these regulations on loan demand from the perspective of institutional management. First, the issues are identified and briefly discussed. Next is an examination of the reactions of various lenders and their professional associations to environmental issues. This is followed by an offering of proactive measures lenders may consider in developing institutional policy on environmental issues. The last section examines the impact of environmental regulations on loan demand.

Environmental Issues Affecting Lenders

Environmental regulations and case law affect lenders in three broad areas: lender liability, borrower liability, and constraints on borrowers' actions. Lender liability for environmental response costs has received the most notoriety among lenders. As is well documented elsewhere (Becker; Bock et al.; Ertley; Ferguson; Henry; Johnson; Miller; Pilko; Turner, Heil, and O'Brien), lenders have been held accountable for costs of cleaning environmentally damaged sites in certain instances. Among such instances are those in which the lender is found to have exercised management control of the borrower or acquired title to real estate by foreclosure or other means and failed to have actively marketed the property within a reasonable time period. In either case the lender's activities have been found to lie outside the protection of CERCLA's "secured creditor" exemption. More troubling to lenders, however, has been the finding of the court in the *Fleet Factors* case. There, the court held that "a secured creditor may incur . . . liability, without being an operator by participating in the financial management of a facility to a degree indicating a *capacity to influence* the corporation's treatment of hazardous wastes" (italics added). [See *United States* v. *Fleet Factors Corporation*, p. 1557, 901 F. 2d 1550 (11th Cir., 1990).] In the wake of the *Fleet Factors* decision, the lending community is left to imagine what measure of loan monitoring or servicing may be undertaken or even authorized in loan documentation without triggering Superfund liability by its inferred "capacity to influence."

From a lender's perspective, the risk in borrower (owner/operator) liability is that a judgment obtained by the government for environmental damage will impair the borrower's ability to satisfy the debt. Because of the potential size of such judgments, this matter is not insignificant.

Environmental constraints on borrower actions have developed over the past two decades. With respect to production agriculture, most of these constraints are applied in the context of pesticide application, air pollution (mainly feedlot odors), water pollution, and soil and water conservation (Bock et al.). Although many matters involved in these issues affect lenders indirectly, some of them may directly affect a borrower's ability to continue as a viable enterprise. Obvious are the costs of regulatory compliance and their impact upon borrower financial strength and borrowing capacity. For example, the Na-

Michael A. Mazzocco is an assistant professor, Department of Agricultural Economics, University of Illinois.

The assistance of Delmar K. Banner is gratefully acknowledged.

tional Pollution Discharge Elimination System (NPDES) permit program and related state programs do not require permits for pollutants from agricultural activities except concentrated animal-feeding operations. Among other examples are enterprises squeezed between "right to farm" laws, which confine production to historic levels and the necessity of expansion to remain commercially viable.

Reactions of Lenders to Environmental Regulations

From an industry perspective, noticeable responses to CERCLA and SARA began to emerge in the late 1980s (Ertley, Ferguson, Forte). Much of this was in the form of protection against the results of *United States* v. *Maryland Bank & Trust Co.* (632 F. Supp. 57, 1986), the first major case identifying lender liability outside the secured creditor exemptions.

Banks and other lenders became aware of their exposure under the law and sought new ways to take cover. The typical response of larger, more sophisticated lenders was the development of detailed environmental policy and procedure manuals (NBD Bancorp, Farm Credit Council, Federal Agricultural Mortgage Corporation). These materials enunciate the steps to be taken for lenders to maintain the "innocent landowner defense" in the event the lender must recover the property. Smaller lenders, such as independent rural banks, have to some extent relied on policy and procedure guidelines recommended by the American Bankers Association (Turner, Heil, and O'Brien). These documents implement a series of activities which duplicate the many requirements of land purchasers in establishing due diligence when conducting an investigation of the property and the history of activities occurring on the property. They also suggest questions to be asked borrowers in establishing the environmental history of the property and items to be observed during an on-site inspection. Suggested protection for lenders includes borrowers' warranties that they are in compliance with all environmental regulations and have obtained all necessary permits, and covenants that they will not violate any environmental regulations and will protect the lender from environmental liability.

Many lenders require a phase I environmental site assessment by an independent firm as a condition of granting loans. These assessments involve site inspections and searches of public records to establish that the site is likely to be clean. Costs for these services are on the order of $2,500, with $5,000 not being uncommon for larger agribusinesses (Commins). The cost is treated as a loan application cost to be paid by the borrower.

Another method used by lenders to avoid environmental liability is the taking of so-called "collar mortgages." Because of the activity around farmsteads relating to animal feeding, chemical storage and mixing, and the location of underground storage tanks and water wells, lenders sometimes exclude the farmstead from the collateral base when securing loans (Farm Credit Council).

Larger, more diversified lenders have retained consulting services of environmental assessment firms in an effort to identify risks of environmental exposure associated with various industries. Agricultural production and food-processing industries generally have low environmental risks, mostly related to improper storage or disposal of routine materials (NBD Bancorp). Many lenders providing operating credit to agribusinesses are not secured by real estate assets. Thus, an evaluation of a borrower's potential environmental liability and its impact on repayment ability is to be conducted as part of the risk assessment. This process receives minimal mention in professional publications within the industry. (See, for example, Federal Agricultural Mortgage Corporation; Turner, Heil, and O'Brien; or Farm Credit Council.)

The overall character of the industry response appears to be similar to that of interest rate risks arising ten years earlier. Recall the emphasis on variable rate loans as a solution to asset/liability gap management, which shifted interest rate risk to borrowers. Unfortunately, borrowers were least able independently to manage interest rate risk. Similarly, the lending industry has developed a protectionist approach in which "lenders will want the closing documents to shift (environmental) liability to the borrower" (Forte, p. 17). This is a rational response to relevant court decisions. In practice, and perhaps in response to those decisions, lenders appear to avoid giving any counsel to borrowers with respect to environmental issues. Rather, lenders are counseled to have their documents require borrowers to warrant their understanding and compliance with relevant regulations (NBD Bancorp; Turner, Heil, and O'Brien; Farm Credit Council, Federal Agricultural Mortgage Corporation). There is, of course, cause for skepticism as to the extent of those borrower understandings.

Lending groups have been active lobbyists during the past year. As a result of lenders' reaction to the *Fleet Factors* decision, the Environmental Protection Agency offered a set of proposed regulations which specifically identify the requirements for maintaining a secured creditor defense against CERCLA and SARA liability and exempt governmental units, including the Resolution Trust Corp. and the FDIC, from liability (Federal Register).

The EPA-proposed regulation specifically states that lenders may take steps to service loans, offer financial and managerial advice, restructure loans, inspect collateral, and, more important, take title to property through foreclosure or other means to protect the debt without jeopardizing their secured creditor exemption from CERCLA liability. Furthermore, lenders would not be required to undertake an environmental assessment to maintain their exemption. The proposed rule also specifies the time within which lenders must commence certain liquidation activities to maintain the secured creditor exemption. This is in direct response to the holding in *Maryland Bank & Trust*, where the court imposed CERCLA liability given that the bank's retention of the property for four years indicated their purpose was commercial gain and not loan recovery. The banking industry responded to the proposed rule with calls for legislative action which would include mention of banks' protection from liability when acting in their capacity as a fiduciary (e.g., managing property held in trust) and relief from liability under other environmental statutes such as the Resource Conservation Recovery Act (RCRA) which governs underground storage tanks (Johnson, Pollard).

As part of this lobbying effort, the congressional testimony included data indicating that out of 2,000 banks responding to a survey by the American Bankers Association, 220 have incurred environmental clean-up costs (Johnson). In the past, many lenders have acquired property sustaining physical damage. Lenders make an investment decision regarding the recoverability of further investment to enhance the property's value or marketability. Environmental damage is no different, despite the EPA's proposed rule. Prospective purchasers may uncover environmental damage through their own due diligence and require the seller to restore the property to usable, remarketable condition prior to any transfer. This may be especially true when the seller is a lender in possession of acquired property. Thus, although the EPA proposes to reduce CERCLA liability exposure of lenders' equity capital, the proposed regulations will not, nor likely should they, guarantee lenders environmentally clean collateral from which to recover defaulted loans.

In the same survey 62.5% of the respondents indicated they had rejected loan applications because of potential environmental liability and 45% discontinued financing certain types of loans, many dealing with fuels, chemicals, and underground storage tanks. News articles (e.g., Kleege) describe lenders' concerns and avoidance of certain transactions. Some industry groups have supported the proposed regulation and similar legislation introduced by U.S. Representative LaFalce and Senator Garn to resurrect the flow of financing to their industries.

Proactive Responses

Absent from these actions and reactions is evidence of lenders undertaking any measures directly helpful to their customers, their communities, or the public at large. Isolated incidence of some proactive steps can be overheard at professional meetings, such as making low- or no-tillage equipment available to customers on a trial basis. But evidence of comprehensive, coordinated environmental awareness and action programs is lacking. The following suggestions may evoke a response.

The posture suggested to lenders in trade publications and policy guidelines is to maintain a comfortable distance between themselves and their borrowers' environmental responsibilities. It is likely to be more beneficial to assume a more informational and educational role of helping customers stay abreast of current, applicable environmental laws and regulations. This could include providing a listing of relevant agency representatives, enumerating such details as NPDES livestock permit requirements and manure storage requirements, listing common sources of potential environmental contamination, and suggesting references for practices to reduce environmental risk. The result would be not only good business, but good stewardship of community resources as well.

Lenders (and economists who propose rational behavior for lenders) have methods of incorporating various sources of risk into their loan pricing mechanisms. As lenders develop more awareness of environmental risks, contributing factors could be accounted for in a loan pricing mechanism. These risk factors could be easily and explicitly identified by both borrowers and

lenders, much the same way tiered interest rates have solvency hurdles which trigger lower rates. Examples include the use of large underground storage tanks, not storing chemicals on cement floors, concentrated feeding operations near navigable waterways, use of non-bulk chemicals, or farms containing wetlands and waterways without sufficient protection. As each of these factors adds to the risk premium charged by lenders, borrowers would have an economic incentive to reduce their own exposure to environmental liability. Whether through information programs or economic incentives, such actions may lower the risk of default resulting from environmental response by various agencies.

Effect on Loan Demand

Changing practices and advancing technologies may result in slightly lower input requirements and operating credit needs in the longer term. In the near term, however, most of the change in loan demand based on environmental regulation will come from borrowers' compliance efforts. Both unfortunate and necessary, much of this loan demand will be for facilities improvements which may generate negative incremental cash flow and income. Thus, analyzing such loan requests may require an individual decision on re-engaging a longer-term relationship with each affected borrower. Examples include investments in manure storage, chemical storage, pavement, dikes, and extraction of underground storage tanks. The magnitude of this loan demand is likely to be dependent upon location, size, and scope of enterprises.

Concluding Comments

Environmental regulations and applicable case law have caused lenders to develop shields from environmental risks. These defense mechanisms have taken various forms, including stronger documentation requirements and avoidance of loans to certain types of businesses. The lending industry has been compelled by court decisions to refrain from taking an active role in environmental regulation compliance. Perhaps the adoption of proposed regulations or legislation which strengthens the secured creditor exemption from CERCLA and SARA liability will cause lenders to reposition themselves to be more proactive in helping their borrowers comply with applicable environmental regulations. Some lenders may begin to witness an increase in loan demand for facilities improvement loans which are neither self-liquidating nor self-sustaining.

References

Becker, Charles F. "Environmental Exposure." *Bank Management*, pp. 34–36. Bank Administration Institute, Aug. 1990.

Bock, C. Allen, W. J. Anaya, J. Deery-Schmitt, and J. Pratt. "Environmental Laws Regulations and Liability as They Apply to Agriculture." Materials prepared for seminar entitled "Environmental Laws, Regulations and Liability," sponsored by the University of Illinois, 10–13 Dec. 1990.

Commins, James A. "Environmental Audits Revisited." *RMA J. Commercial Bank Lending* no. 9 (1990), pp. 13–17.

Ertley, Linda M. "Lender Awareness of Underground Storage Tanks." *RMA J. Commercial Bank Lending*, no. 4 (1988), pp. 41–51.

Farm Credit Council. *Environmental Risk Management: Sample Policy and Practices*. Washington DC, April 1990.

Federal Agricultural Mortgage Corporation. "Environmental Survey." *Farmer Mac Securities Guide*, appendix AI. Washington DC, 1989.

Federal Register, June 24, 1991. 56(121):28798–28810.

Ferguson, Jerry T. "Detecting Environmental Risk." *Mortgage Banking*, pp. 69–72.

Forte, Joseph Philip. "Environmental Liability Risk Management." *J. Agr. Lending* 3(1989):14–20.

Henry, Evan C. "Practical Approaches to Environmental Risk Avoidance in Agricultural Real Estate Lending." Paper presented at the ABA National Institute Fourth Annual Symposium on Agricultural and Agribusiness Credit, San Francisco, 2–3 May 1991.

Johnson, Robert T. "Lender Liability Under Superfund." Statement of the American Bankers Association before the Subcommittee on Policy Research and Insurance of the Committee on Banking, Finance and Urban Affairs, U.S. House of Representatives, 10 July 1991.

Kleege, Stephen. "Kansas Bankers Run from the Blob." *American Banker*, 7 Dec. 1990.

Miller, Dwight W. "Environmental Liability for Agricultural Lenders: Ways to Minimize the Risks." *Agricultural Lenders Guide to Environmental Liability*, pp. 17–22. Washington DC: American Bankers Association, 1990.

NBD Bancorp, Inc. *Environmental Guideline and Reference Manual*. Detroit MI, 1989.

Olexa, Michael T. "How Federal Environmental Statutes Impact the Use of Agricultural Chemicals." *Agricultural Lenders Guide to Environmental Liability*, pp. 75–100. Washington DC: American Bankers Association, 1990.

Environmental Quality Constraints and Farm-Level Decision Making

Calum G. Turvey

The linkage between environmental quality degeneration and agricultural production decisions is well established and has been recognized as an important target for agricultural and environmental policy in Canada and the United States. In Canada, for example, proactive policy guidelines call for an overall reduction in pesticide use of 50% by the year 2002 and a 50% reduction in soil and phosphate loading in surface water by the year 2000. In the United States, enabling legislation enacted under the 1985 farm bill established cross-compliance under the conservation reserve program; under the Water Quality Act of 1987 soil conservation districts will soon have to establish plans to control non-point-source pollution, including runoff from farms (Malone); Brownbach, Krissek, and Maxwell provide evidence of increased use of legislation and civil penalty to curb pesticide misuse in Kansas; and the state of Iowa has the regulatory authority to impose soil loss and loading restrictions on individual farmers (Malone). Legislatures and courts now recognize that it is the responsibility of farmers to establish and maintain soil and water conservation practices as well as erosion control practices, and these practices are in the interest of the public good and within the domain of state power (Hamilton, pp. 236–39). Externalities motivating these initiatives are derived from food safety issues, recreational costs, water treatment costs, water transportation infrastructure, and increased risk of flooding (Fox and Dickson, Malone).

The objective of this paper is to examine agricultural management issues as they relate to the possible introduction of enforceable regulatory or legal legislation. Considered purely in a normative context, the existence of environmental quality constraints on soil loading for a southwestern Ontario watershed as a specific type of *ex ante* regulation is assumed. *Ex ante* regulations (e.g., licensing, restricting tillage practices and/or effluent discharge) are intended to affect an activity before an externality is generated, whereas *ex post* policies (e.g., effluent taxes, fines, lost liability) are intended to encourage desirable behavior by generating costs after the externality has been generated (Kolstad, Ulen, and Johnson; Hirsch). *Ex ante* regulations restricting pollution have been shown to be very efficient in terms of input use, output, and profitability (Helfand). In this study best management practices (those that control non-point source pollution and are socially and economically acceptable) are investigated within a profit-maximizing framework to establish the marginal costs to farmers of the environmental quality constraints. Inferences about the potential effects on farmers' financing and investment behavior are then made under the assumption of *ex post* liability and effluent taxes. A second aspect of the problem includes rainfall as a stochastic variable to illustrate how, in a regulatory and/or legal environment, environmental quality constraints may be violated despite farmers' best efforts.

Background

Agricultural economists have generally discarded the view that problems of long-run productivity are sufficient for public policy intervention (van Kooten and Furtan), focusing rather on off-site damage from soil erosion, sediment and phosphate loading into surface water, and ground water nitrogen loading (Fox and Dickson, Stonehouse and Bohl). Four public policy instruments available to government for regulating these externalities are voluntary compliance, financial incentives, regulation, and liability. Of these, voluntary compliance and financial incentives are the most common approaches used by governments. Questions still arise about the efficiency of financial incentives if those incentives do not at least equal the op-

Calum G. Turvey is an assistant professor in the Department of Agricultural Economics and Business, University of Guelph.

Thanks are extended by the author to Glenn Fox, Allen Featherstone, Vincent Amanor-Boadu, and Wayne Howard for their helpful comments.

portunity costs facing farmers. As well, voluntary compliance and other *ex ante* regulations in the United States have had only mixed success (Malone, Stonehouse and Bohl, and citations therein). Thus, in the absence of effective means to induce farmers to reduce effluent discharge and other pollutants, it may be necessary for legislators to impose *ex ante* (e.g., restricting surface water soil loading) regulations enforced by *ex post* civil penalties (e.g., fines or effluent taxes), *ex post* liability, or a combination of both.

From an economic perspective, a minimal standard of care—that is, adherence to, but not necessarily exceeding, a particular regulation—can be achieved through a combination of *ex ante* and *ex post* policies (Shavell). *Ex ante* regulation can be effectively enforced through the deterrent effect of *ex post* liability or effluent taxes. Even when the outcome of damages is uncertain, Shavell argues that a combination of *ex ante* and *ex post* liability is efficient. Strict liability, when the outcome is uncertain, will encourage high risk producers to take more than the minimum standard of care because adherence to this minimum, or due diligence, is not a sufficient defense to escape liability. On the other hand, Shavell argues that the standard of care should be sufficiently lax so that those who would face unusual costs of care, pose lower risks, or are affected by flaws in the probabilistic methods of enforcement should escape liability.[1] Kolstad, Ulen, and Johnson argue that regulation and liability can effectively work together because of the ambiguous nature of the definition of the basic standard and the riskiness of court judgments. If individuals account for the uncertainty of the legal standard of care and uncertainty about liability judgements, they may be overly cautious.

Agricultural economists have for the most part taken a global view of environmental quality, with few studies reporting the impacts of regulation and/or liability at the farm level (Jacobs and Casler). Assuming that farmers are pure profit maximizers, environmental regulation will impose opportunity costs in terms of foregone profits. In terms of management decision making, the impact of these costs can be diverse with some farmers, particularly those with low debt and fixed costs, still being profitable, while others may be put under financial strain. The farm-level effects of environmental quality constraints are therefore defined by the marginal costs of the constraints. Hence, the following sections focus primarily on these costs with the concomitant management impacts implied by the opportunity cost relationships.

Methods

To illustrate the on-farm effects of environmental regulation a profit-maximizing linear program of a southern Ontario watershed is modeled. The crops to be grown in the two-period model are continuous corn using conventional tillage for each period, continuous corn using no-till, soybeans in rotation with corn using conventional tillage, and soybeans in rotation with corn using no-till. Constraining the model is a restriction on the total amount of soil loading into surface water from the watershed. The 351.9 hectare (ha.) watershed is comprised of 432 cells, each with a unique slope and erodability factor. Because optimization permitted growing any crop or rotation on each cell, there were (4 × 432) 1,728 first-year growing activities and (6 × 432) 2,592 second-year activities. The optimizing model is similar to that used in Jacobs and Casler, Wade and Heady, and Turvey and Weersink.

Soil loading quantities (tonnes/ha.) were derived from the GAMES simulation model (Guelph Model for Evaluating Effects of Agricultural Management Systems on Erosion and Sedimentation, Dickinson and Rudra), which describes and predicts soil loss by fluvial erosion and the delivery of soil from field to stream using the universal soil loss equation (USLE) (Wischmeier and Smith). The GAMES Model was used to obtain soil-loading factors for each cell in the watershed and each cropping activity. This procedure allowed a remedial targeting strategy to be investigated. Remedial targeting (Dickinson, Rudra, and Wall) implies that conservation practices are applied first to the most erosive areas in the watershed. This eliminates a large proportion of soil loading by applying conservation methods to a relatively small area.

To examine the issue of risk, the GAMES model was run for rainfall indices (R) of 90, 100, and 110. The constrained optimization model was run using R = 100 as the benchmark. The effects of uncertain rainfall were obtained by multiplying the solution vectors of this base by the

[1] Probabilistic methods of enforcement relate to the problem of assigning liability when a number of individuals contribute to the externality. For example, in the case of non-point agricultural pollution, the law may conclude that all farms in watershed would have contributed to the externality with a probability equal to their individual shares of acreage adjacent to the stream, river, or lake (see Hirsch, pp. 196–98).

soil loading factors obtained from the GAMES $R = 90$, and $R = 110$ simulations.

Results

The Deterministic Model

The solution to the average rainfall ($R = 100$) model is presented in table 1. Environmental quality constraints ranged from 0 at which point soil loading equalled 121.7 tonnes to restricting total watershed loading to 20 tonnes over the two-year period. Gross margins range from a high of \$286,968 to \$256,826, implying that the average cost of the environmental quality constraint ranges from 0 to \$296.38 per tonne (\$286,968–\$256,826)/(121.7T.–20T.)) for the two years combined. The optimum strategy is to grow continuous corn using conventional tillage for the unconstrained model; but as the soil loading constraint increases, no-till corn is substituted. The marginal costs of the environmental quality constraint obtained from the quality constraints shadow price range from \$30.43/T to \$1401.53/T. From figure 1, marginal costs increase at an increasing rate as a result of the remedial targeting objective; for example, constraining soil loading to 110 T. requires (in the first year) that continuous corn be reduced from 352.9 hectares to 348.0 hectares, to obtain 11.7 T reduction. However, as the constraint size increases, incrementally more conventional corn is taken out of production.

The effect of regulation can, therefore, have an impact on farm-level decision making. Conservation laws, which order a reduction in soil loading, cannot be enforced without some economic costs to farmers. Yet, the opportunity costs would run much higher than a simple reduction in farm profits; for example, farmers must also contend with the associated costs of meeting fixed financial obligations. Dual objectives of maximizing profits subject to satisfying environmental quality constraints and constraints on fixed financial obligations may over some range be infeasible. The effects of environmental quality constraints can, for some farmers, be far reaching, with reduced profitability, cashflow, liquidity, credit reserves, and investment.

The regulatory regimes described in the previous section can either mitigate or exacerbate these on-farm effects. For example in figure 1 an assumed marginal social cost curve intersects the MC of environmental quality constraints at 40 tonnes.[2] The policy objective is, therefore, to reduce loading by 81.7 T. over the two-year

[2]That the social cost curves are assumed and not measured needs to be emphasized. Over the range of effluent reduction, social costs decrease at an increasing rate, implying decreasing returns to scale. If the opposite were assumed, then so would be increasing returns to scale. Few studies have estimated the social cost of soil loading. One study by Fox and Dickson for Ontario Watersheds estimated average costs for angler fishing in Ontario alone to be Can. \$52.93/T (see p. 34). But in the Willamette Valley in Northwestern Oregon, Moore and McCarl estimate the average costs of water treatment, road maintenance, river channel maintenance, reservoirs, and hydroelectric power plants to be only U.S. \$2.63 per acre. There is little, if any, consensus on how costs should be measured and how often to measure them.

Table 1. Soil Loading, Opportunity Costs, and Best Management Strategies Under Environmental Quality Constraints

	Soil Loading (Tonnes)				Year 1 Corn		Year 2 Corn	
Profit	Average Rainfall	Low Rainfall	High Rainfall	Marginal Cost of Constraint	Conventional Tillage	No-till	Conventional Tillage	No-till
(\$)				(\$)				
286,968	121.7	49.30	249.70	30.43	351.9	0	351.9	0
286,531	110	43.60	219.90	47.73	348.0	3.9	347.7	4.2
285,874	100	40.10	201.60	76.95	340.9	11.0	342.8	9.1
285,035	90	36.60	182.50	91.08	334.5	17.4	333.8	18.1
284,036	80	33.19	159.35	117.84	323.9	28.0	326.1	25.8
282,690	70	29.69	135.28	172.65	313.1	38.8	313.2	39.7
280,787	60	26.34	113.86	209.84	296.9	55.0	293.6	58.4
278,134	50	23.40	92.04	340.99	270.0	81.9	271.8	80.1
273,833	40	19.24	73.13	545.58	232.0	119.9	231.0	120.9
267,206	30	15.14	54.62	814.30	170.8	181.1	170.7	181.2
256,826	20	8.89	37.62	1401.53	84.8	265.3	89.8	266.1

Note: Soybeans were not grown either continuously or in rotation with corn.

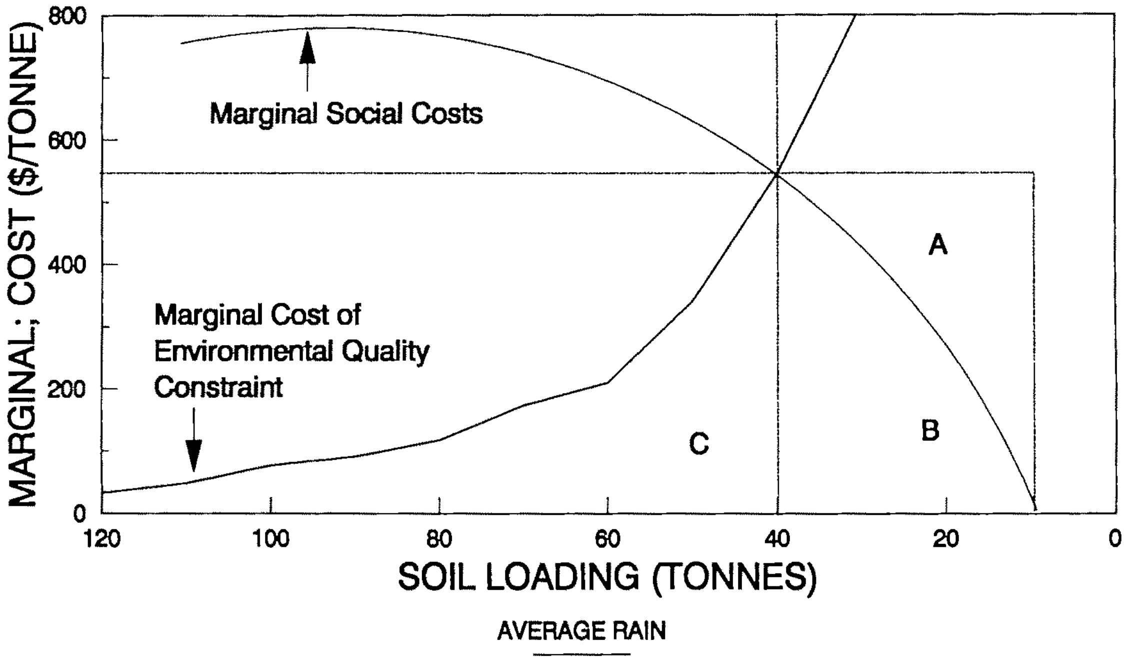


Figure 1. Regulation of soil loading with deterministic rainfall

period, which causes a reduction in gross margins to $273,833. To achieve this, a policy of financial incentives to encourage voluntary compliance would return area *C* to the farmers. From table 1, this amounts to a total of $13,135. The net watershed revenue is, therefore, $286,968, which is the same as the unconstrained model.

Ex post policies, such as effluent taxes or liability for harm done, are means to enforce a specific action. In the example, the social optimum implies an effluent tax of $545.58 per T. on each tonne still delivered to the stream (Jacobs and Casler). Not only do watershed farmers forgo opportunity costs of $13,135 (area *C*), but a tax of $21,823 is levied (areas $A + B$). Assuming that area *B* is twice area *A*, 2/3 of the effluent tax will go to environmental cleanup ($14,549) while 1/3 enters the public purse ($7,274). The total cost to farmers of this effluent tax policy is $34,958. Strict liability would make producers liable for all damage. While costs associated with area *C* would accrue from an *ex ante* regulation farmers would also be subject to liability of area *B*. Because the total cost of liability is less than the cost of taxation ($27,684), this would be preferred.

The above resolutions to the problem of soil loading are all pareto superior to the do-nothing option because a net increase in social welfare will result. If *ex post* policies are strictly enforced, then reduction beyond the social optimum will incur higher marginal costs but with reduced taxes or liability, whereas reduction below the social optimum will result in lower marginal costs but with increased taxes or liability. Within this class of policies, however, a strict liability rule would be pareto dominant because it provides the greatest societal benefits at a minimal cost to farmers. For example, if the financial incentives approach is used, the net societal benefit is the area above the producer's cost curve and below society's cost curve less area *C*. Under a liability rule the net societal benefit is the area between the two cost curves which is superior by the amount of *C*. These conclusions are consistent with those argued by White and Wittman.

The Stochastic Model

Table 1 and figure 2 illustrate the effects of stochastic rainfall. As rainfall increases so does the amount of surface water soil loading. For example, if an environmental quality constraint restricting soil loading to 40 T is based on an average USLE rainfall index of 100 but the actual

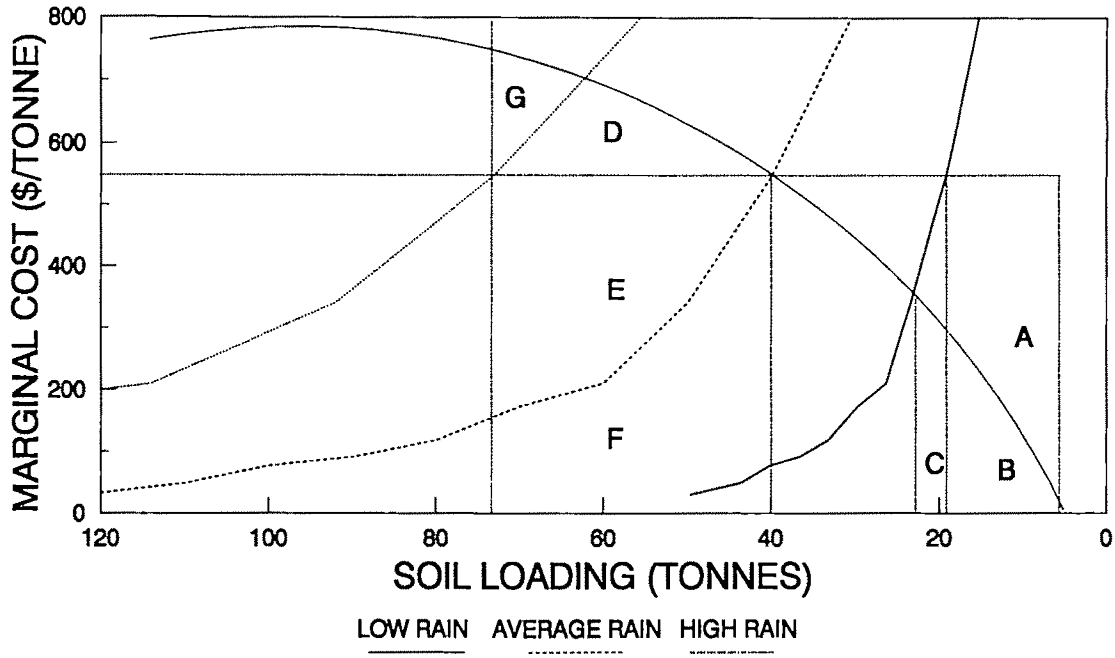


Figure 2. Regulation of soil loading with stochastic rainfall

rainfall index is 110, the simulated soil load is 73.13 T. As before, effluent taxes of $545.18 per tonne are charged on all soil loading, and strict liability is measured by the area to the right of each rainfall curve and below the social cost curve. (I assume no variable or fixed cost increment to rainfall, nor do I make allowances for yield differences.) Under a low rainfall scenario, the effluent tax liability is substantially reduced to the area $A + B$ in figure 2, as is liability which is defined by area $B + C$. A rainfall outcome less than expected will, therefore, reduce the liability facing farmers. The impact of a high rainfall outcome is more severe than the deterministic case. In addition to the costs incurred in the deterministic model (fig. 1), effluent taxes would increase by the area $E + F$, or an increase of approximately $18,000 [approximately (73 T − 40 T) × 545.58]. Under a liability rule, incremental liability increases by the area $D + E + F + G$.

The effects of *ex post* liability and taxation can adversely affect farmers, not only in terms of profits and cashflows, but they also add a new element of uncertainty into the management strategy. A fair legislation to control effluent discharges would necessarily have to recognize due diligence as a reasonable defense, or, as Shavell suggests, setting a standard of care which is sufficiently lax to ensure that unusual costs do not arise. Kolstad, Ulen, and Johnson argue that the standard of care should be set lower than the social optimum. A parallel argument to theirs would be that uncertainty about the outcome would lead farmers to take precautions exceeding the social optimum, thereby encouraging an inefficient and nonoptimal response; if farmers' perception is that rainfall will be less than expected, so that the marginal costs of precaution will exceed the costs of liability, then less precaution will be taken; but, if the risk perception is that rainfall will exceed the expected level, marginal costs of liability will exceed the marginal costs of precautions and more precaution will be taken.

Conclusions

This paper identifies the possibility of invoking *ex ante* regulation and *ex post* liability to achieve policy objectives about environmental sustainability. In particular, surface water soil loading for a southern Ontario watershed was used to examine farm-related issues in cognizance of the regulatory policy. Evidence was presented that marginal costs to farmers, under *ex ante* regulation, increase at an increasing rate. Farmers will respond by substituting conservation tillage methods for traditional methods, but in so doing

they will forego profits. For some farmers, this decrease in profitability may result in diminished investment capacity because of reduced cashflow, liquidity, and credit reserves. At the extreme, environmental regulation may increase financial risk especially for highly leveraged farmers.

References

Brownbach, S., G. P. Krissek, and S. D. Maxwell. "An Overview of Kansas's Regulation of Agricultural Chemicals and Pesticides." *J. Agr. Tax and Law* 13(1991):66–72.

Dickinson, W. T., and R. P. Rudra. *GAMES: The Guelph Model for Evaluating Effects of Agricultural Management Systems on Erosion and Sedimentation User's Manual*, pp. 126–86. School of Engineering Tech. Rep., University of Guelph, 1990.

Dickinson, W. T., R. P. Rudra, and G. J. Wall. "Targeting Remedial Measures to Control Non-point Source Pollution." *Water Resour. Bull.* 26(1990):499–507.

Fox, G., and E. J. Dickson. "The Economics of Erosion and Sediment Control in Southwestern Ontario." *Can. J. Agr. Econ.* 38(1990):23–44.

Hamilton, N. D. "Adjusting Farm Tenancy Practices to Support Sustainable Agriculture." *J. Agr. Tax. and Law* 12(1990):226–52.

Helfand, G. E. "Standards Versus Standards: The Effects of Different Pollution Restrictions." *Amer. Econ. Rev.*, 81(1991):622–34.

Hirsch, W. Z. *Law and Economics: An Introductory Analysis*, 2nd ed. San Diego: Academic Press, 1988.

Jacobs, J. J., and G. L. Casler. "Internalizing Externalities of Phosphorous Discharges from Crop Production to Surface Water: Effluent Taxes versus Uniform Reductions. *Amer. J. Agr. Econ.* 61(1979):309–13.

Kolstad, C. D., T. S. Ulen, and G. V. Johnson. "*Ex Post* Liability for Harm vs. *Ex Ante* Safety Regulation: Substitutes or Complements." *Amer. Econ. Rev.* 80 (1990):888–901.

Malone, L. A. "The Renewed Concern over Soil Erosion: The Current Federal Programs and Proposals." *J. Agr. Tax. and Law* 10(1989):310–54.

Moore, W. B., and B. A. McCarl. "Off-site Costs of Soil Erosion: A Case Study in the Willamette Valley." *West. J. Agr. Econ.* 12(1987):42–49.

Shavell, S. "Liability for Harm versus Regulation of Safety." *J. Legal Stud.* 13(1984):357–74.

Stonehouse, D. P., and M. Bohl. "Land Degradation Issues in Canadian Agriculture." *Can. Pub. Pol.* 16 (1990):418–31.

Turvey, C. G., and A. J. Weersink. "Economic Costs of Environmental Quality Constraints." *Can. J. Agr. Econ.*, forthcoming in proceedings of the Workshop for Sustainable Agriculture: Economics Respectives and Challenges, CAEFMS, Winnipeg, Manitoba, 5–7 May 1991.

Van Kooten, G. C., and W. H. Furtan. "A Review of Issues Pertaining to Soil Deterioration in Canada." *Can. J. Agr. Econ.* 35(1987):33–54.

Wade, J. C., and E. O. Heady. "Controlling Nonpoint Sediment Sources with Cropland Management: A National Economic Assessment." *Amer. J. Agr. Econ.* 59 (1977):13–24.

White, M. J., and D. Wittman. "A Comparison of Taxes, Regulation and Liability Rules Under Imperfect Information." *J. Legal Stud.* 12(1983):413–26.

Wischmeier, W. H., and D. D. Smith. "Predicting Rainfall Erosion Losses—A Guide to Conservation Planning." Washington DC: U.S. Department of Agriculture, Science and Education Administration Handbook No. 537, 1978.

Financing Agriculture Under Changing Environmental Regulation: Discussion

Charles B. Moss

In general, the papers presented in this session focused attention on the effects of recent environmental legislation on the supply of and demand for capital in agriculture. Olexa discussed both legislation and cases with particular emphasis on those provisions of CERCLA and SARA which could affect agriculture. Mazzocco followed with a discussion of the observed and probable responses of financial intermediaries. Turvey focused on impacts of soil erosion constraints on the choice of crop activities. Given the nature of these three papers, I will attempt to propose an agenda for agricultural finance as it relates to changing environmental regulation.

The easiest recommendation, and in some sense the most useless, is to indicate that our teaching programs both on and off campus must be expanded to keep pace with the rapid evolution of environmental awareness. The immediate reaction of additional course work has limited appeal. Instead, I propose that topics such as the material from Olexa be integrated into existing agricultural policy or finance courses.

A large portion of the emerging problem of environmental considerations in agricultural finance requires a phrasing of the problem from the financial intermediaries point of view. We now should consider financial intermediaries in the development of programs. First, undergraduate and graduate programs should be formulated consistent with the needs of financial institutions. Second, extension or off-campus educational programs must focus on the needs of bankers, both directly as students and indirectly through the education of producers in the concerns of financial intermediaries. Last, education through research must be refocused to incorporate the needs of intermediaries. In particular, the research agenda and delivery must consider the requirements of agricultural intermediaries.

Olexa also raises several new research perspectives for agricultural economists. First, the law allows some defense to lenders under the concept of due diligence. Due diligence can be established through investigative decisions including environmental audits. However, the nature of an environmental audit itself implies risk. The agent providing the audit simply attests whether or not the sample includes environmental contaminants. This procedure raises the specter of the adequacy of the sample. More specifically, given some history of the property, how many samples are necessary for the lender to be comfortable? One approach to this problem may parallel Kaylen, Devino, and Proctor in the analysis of elevator failures.

The question of environmental quality also extends to the current loan portfolio. For example, if a particular farm loan is questionable for some reason, one action a lender may consider is the suggestion of a marketing plan, such as government program participation or the use of forward marketing. Care should be exercised with this scenario that the lender does not exhibit capacity to influence as defined in *Fleet Factors*. In addition, a bank that decides not to foreclose on collateral suspected of being contaminated may be forced to recognize a larger loan loss. This could imply that a previously solvent bank is in fact insolvent because of environmental hazards.

Mazzacco provides a practical guide to lenders. Basically, he breaks the increased risk to agricultural lender down into three categories. First, the lender could be held liable for the cleanup, as stated in Olexa. Second, the author recognizes that borrower liability has increased, causing an increased probability of farm bank-

---

Charles Moss is an assistant professor of food and resource economics, Department of Agricultural Economics, University of Florida.

This is Florida Agricultural Experiment Station Journal Series No. N-00253.

ruptcy and nonpayment through direct environmental action. Third, he raises the possibility of farm bankruptcy through farmers attempting to meet the requirements of the environmental regulations.

In outlining the bankers options Mazzocco compares the alternatives available to the banker to the banker's attempt to shift risk to the farmers using variable interest rate instruments. He notes the attempt to establish due diligence using investigations into the past uses of the property and environmental site assessments. Either approach increases the cost of obtaining a loan either through loan initiation fees or interest rates. In addition, the bank may be forced to increase its required margin to protect itself against potential environmental litigation.

A more nebulous effect may be the denial of credit on certain uses and collar loans. In high-leverage cases, these restrictions may make attaining sufficient capital impossible. A related question involves the collar loan. If the farmstead is not collateralized, can it be considered in the computation of solvency? This could be particularly important for plant facilities such as barns, granaries, or lots because these assets may contribute substantially to the firm's value.

Turvey examines the effect of environmental regulations on the farm through constraints on runoff. The analysis finds a shift away from a more profitable continuous corn rotation to a reduced tillage operation under environmental regulation. To tie to the effect of environmental regulations on agricultural credit markets, Turvey draws conclusions based on cash flow requirements. He speculates that sufficiently stringent environmental regulations could cause certain farmers to fail to meet cash flow obligations.

I would like to extend Turvey's model by bringing in the potential effect of environmental regulations on the financial intermediary. Specifically, as indicated earlier, environmental considerations will probably increase the cost of borrowing. In addition, Turvey indicates that the shift to more environmentally sound cropping practices implies less profit. Consider the optimal debt formulation proposed by Collins:

$$\delta = 1 - \frac{\rho\sigma_A^2}{\bar{R}_A - K}, \tag{1}$$

where δ is the optimal leverage, ρ is the risk aversion coefficient, σ_A^2 is the variance on asset returns, $\bar{R}_A$ is the expected return on assets and K is the cost of capital. Following the results of Turvey and the implications of Mazzocco, environmental regulations imply a lower return on assets and an increased cost of capital. Therefore, the optimal leverage would decline. Further, as indicated by Moss, Ford, and Boggess, the decline in optimal leverage may be insufficient to compensate for the reduced margin. Thus, the probability of farm bankruptcy may rise.

Another interesting question ignored by Turvey is the effect of additional investment. For example, one response to soil erosion could be terracing. Similarly, dairy farmers facing phosphorous runoff problems in Florida can invest in containment facilities ranging from simple ponds to complete confinement barns. These possibilities raise a completely different dimension to the environmental question.

References

Collins, R. A. "Expected Utility, Debt-Equity Structure, and Risk Balancing." *Amer. J. Agr. Econ.* 67 (1985):627–29.

Kaylen, M. S., G. T. Devino, and M. H. Procter. "Optimal Use of Qualitative Models: An Application to Country Grain Elevator Bankruptcies." *S. J. Agr. Econ.* 20(1988):119–25.

Moss, C. B., S. A. Ford, and W. G. Boggess. "Capital Gains, Optimal Leverage, and the Probability of Equity Loss: A Theoretical Model." *Agr. Finan. Rev.* 49(1989):127–34.

Financing Agriculture Under Changing Environmental Regulation: Discussion

Neil E. Harl

The papers by Olexa, Mazzocco, and Turvey explore in two separate settings the use of law as a partial or total substitute for the market. I say two separate settings because the Olexa and Mazzocco papers deal with a common theme. Indeed, there is substantial overlap between those two papers.

Lender Liability

Olexa focuses attention upon an important and highly controversial area of cost externalities, hazardous waste disposal. Merely imposing civil regulations or criminal sanctions or both on waste disposal is insufficient to produce a satisfactory outcome where the hazard surfaces some time after the disposal event or events and (*a*) the responsible party is unknown; (*b*) the responsible party is dead, bankrupt, or otherwise unable to respond in damages; or (*c*) the property involved has been conveyed to a good faith purchaser who is and was unaware of the hazard. These shortcomings of civil and criminal regulatory approaches have led to fastening liability to the property interests involved on an ongoing basis even to the extent that individuals and firms acquiring property interests in the affected resources assume liability beyond the value of the resource.

One result of such an approach is to introduce an additional element in resource valuation. Resources are properly valued at a level less than what would otherwise be fair market value by as much as the present value of the cost to meet the imposed clean-up requirements. Inasmuch as the presence of hazardous waste disposal problems may not be actually known or readily discernible, an element of additional uncertainty is injected into the valuation process. Indeed, the required assumption of liability for cleanup is having an easily predicted effect of encouraging those who are contemplating acquiring fee simple ownership (or ownership of even lesser estates) in resources or who are considering lending funds with resources as collateral to take additional steps in an effort to assess, systematically, the probability of hazardous waste disposal in or on the resource. This will likely continue to be the most common response of lenders, for there is little reason to believe the lender's problem will be totally resolved by further legislation.

With required assumption of liability for cleanup of hazardous waste disposal sites, resources are properly valued at less than what would otherwise be fair market value. Indeed, some lenders have effectively made secured loans only to discover that the loan is unsecured. Even worse, as viewed by the lender, is the potential liability beyond zero collateral value as the lender assumes financial responsibility beyond the value of the resource as collateral.

The key issue, with which the Congress has grappled for some time, is where the line should be drawn as to responsibility for liability beyond the value of the resource. Few dispute the reduction in value of the resource (both in resource exchange and as collateral) for cleanup costs. The question is what specific interests in resources should be viewed as sufficient to support imposition of liability beyond resource value. Guidelines are difficult to construct and would presumably depend upon reasonable expectations of the parties. Thus, a lender with a first mortgage on a resource in an amount that is modest in relation to the reasonable perceived value of the resources has a more compelling argument for nonliability than a lender holding a "junk bond"-type interest that places the lender in juxtaposition with equity interests on a debt-

Neil E. Harl is Charles F. Curtiss Distinguished Professor in Agriculture and a professor, Department of Economics, Iowa State University.

Journal Paper No. J-14715 of the Iowa Agriculture and Home Economics Experiment Station Project No. 29620.

equity continuum. The Olexa paper would be strengthened by placing the problem in a theoretical context, although the approach taken in the paper provides useful insights with the current state of the law on this important topic.

I would readily acknowledge that placing the problem in a theoretical context implies an intent on the part of Congress to create a rational, equitable solution. That is not always the case, and it is not the case here. As is often true with secondary environmental liability, fairness and equity are not prominent features of the legislation. Secondary liability is not meant to be fair and equitable. It is meant to produce results—quickly and definitively. The result is that environmental cleanup is accomplished without the delays, often nearly interminable, that accompany fault based upon culpability. One can evaluate CERCLA only by considering that factor.

Regarding Mazzocco's paper, I discovered substantial overlap with Olexa's paper, but with the following specific remarks directed to Mazzocco:

(*a*) Near the bottom of the second unnumbered page, Mazzocco states: "Although many matters involved in these issues [an array of cost externalities in agriculture] affect lenders indirectly, some of them may directly affect a borrower's ability to continue as a viable enterprise." Then Mazzocco states: "For example, the National Pollutant Discharge Elimination (NPDES) Permit Program and related state programs do not require permits for pollutants from agricultural activities except concentrated animal feeding operations." The implication seems to be that NPDES compliance may "directly affect a borrower's ability to continue as a viable enterprise." I have a great deal of difficulty with that conclusion, at least on a general basis up to now. The costs of compliance with that legislation are only rarely enterprise threatening in nature.

(*b*) The impression one gets is that small rural banks have for some time been exercising due diligence in an environmental sense. In late 1987, I gave a paper at the American Bankers Association annual agricultural conference and, with the exception of one large West Coast lender, I noted very little interest when I discussed lender liability for environmental problems. Most lenders, and virtually all rural lenders, started taking steps to protect themselves from environmental liability only in about the past three years and some do not take such steps to this day.

(*c*) I have substantial difficulty with the statement that the overall character of the industry response appears to be similar to the interest rate risk of ten years ago. Of course lenders want to shift the risks to borrowers. Lenders do not assume the risks of entrepreneurship and do not take on the risks of equity capital. To do that requires more compensation than lenders are receiving with conventional loans.

Borrowers want to borrow pure debt capital and shift as much risk as possible to the lenders. Lenders want to lend pure debt capital and shift all risks to the borrower. Thus, it is not unexpected that lenders will try to shift the risks to borrowers in documentation, loan review, and investigation and various kinds of hold harmless assurances.

It is almost certain that lenders will do the same in the face of potential environmental costs—reduce, as much as possible, the probability of lender liability.

One final word: I am far less confident of the efficacy of the collar mortgage solution to the problem. My observation has been that the greater problem is that the more remote parts of the premises are more likely sites. Those are the areas where all of the old batteries are buried, the half-empty paint cans were tossed, old farm equipment was disposed of with oil still in the gear cases. I fear that the collar mortgage gives a false sense of security.

Suggestions that lenders should be expending resources to help borrowers deal with the borrower's problem is worthy of comment. We learned, in the 1980s, of the downside of a non-arm's-length relationship between lender and borrower. Lenders, I believe, learned that lesson well. There is, understandably, a great deal of reluctance in a paternalistic effort by lenders with respect to borrowers and the borrower's problem.

Influencing Farm Management Decisions

The paper by Turvey extends conventional inquiry with a focus on tillage and other management practices under uncertainty. A major area of concern, properly identified by Turvey, is the level of rainfall. Expectations as to rainfall level can influence the management practices utilized on erosive land. An issue not raised by Turvey is whether those with an economic interest in land (notably the holder of the fee simple interest) should be expected to bear responsibility for all possible levels of rainfall. Under the National Pollution Discharge Elimination System (NPDES), after considerable discussion and de-

bate in 1973–74, the Environmental Protection Agency accepted administratively the argument that owners of animal feedlots should be expected to construct facilities and to engage in management practices up to a 25-year, 24-hour rainfall event. Beyond that level, society assumes the costs of externalities. A useful extension of the work by Turvey would be to examine the effects of such assumption of responsibility by society for successively higher levels of rainfall amount and intensity.

Turvey recognizes that the financial impacts of various policies on farmers can be severe. The implication is that the financial impacts are in the form of liability costs or increased costs of compliance otherwise. What is not recognized explicitly is that the imposition of costs is likely to affect land values, not merely reduce the level of firm or enterprise profit. This has important implications for lenders whose collateral values may be diminished as well as for farmers whose net worth may be affected. A further question is the effect on land use patterns as the costs of compliance encourage a land use shift to a less erosive use such as grazing.

The idea of imposing a standard of care is fraught with problems, particularly if a standard of care is to be "sufficiently lax to ensure that unusual costs do not arise," as suggested by Turvey. A regulatory approach designed to avoid such "unusual costs" is often complex and difficult for resource owners to comprehend. However, creating a standard of care that is dependent upon some unspecified index of laxness seems to be a sure prescription for dispute and litigation.

Discounting Human Lives

Maureen L. Cropper, Sema K. Aydede, and Paul R. Portney

Over the last twenty years, economists have taken a strong interest in the evaluation of programs that save lives. The almost exclusive focus of their research, however, has been ascertaining individuals' willingness to pay for marginal reductions in annual mortality risk or, conversely, the compensation individuals would require to bear added risk (Jones-Lee, Mishan).

While it is critically important to understand the valuation of slight changes in mortality risk, it is not the only issue concerning life saving that merits attention. Frequently, for example, regulatory agencies are reluctant to assign dollar values to reduced mortality risks; instead, they evaluate life-saving programs solely on cost-effectiveness grounds; that is, they rank programs on a cost-per-life-saved (CPLS) basis. This raises a particularly thorny question, however, when different programs save lives at different times. For instance, imagine two regulatory programs that would cost society the same amount to undertake, one of which would save ten lives immediately, the other ten lives but only after fifty years (to make matters simple, assume the life-years saved are identical, too). Do both programs have the same CPLS? Or, should the lives saved by the latter program be given less weight (implying a higher CPLS) because they are more distant? A recent and heated dispute between the Office of Management and Budget and the Environmental Protection Agency revolved in large part around this seemingly arcane question.

The general issue in this debate, and the subject of this paper, is individuals' marginal rates of substitution between lives saved at different points in time. By interviewing random samples of individuals and confronting them with choices between hypothetical pairs of life-saving programs, we infer marginal rates of substitution for lives saved at different times. Among other things, we are interested in whether these rates differ for different horizons or are constant, whether they vary systematically with individuals' socioeconomic characteristics, and whether at least some individuals disregard altogether lives saved beyond some future date.

Estimating Marginal Rates of Substitution for Life Saving

To measure the number of lives saved in the future that are equivalent to saving one life today, we confronted people with questions such as the following:

Question 1

> Without new programs, 100 people will die this year from pollution and 200 people will die 50 years from now. The government has to choose between two programs that cost the same, but there is only enough money for one.
>
> Program A will save 100 lives now.
> Program B will save 200 lives 50 years from now.
>
> Which program would you choose?

Two points about the question deserve emphasis. First, it is deliberately abstract. What each program will accomplish is vague, except that it will reduce pollution and, thus, save lives. The purpose is to focus attention on the timing of lives saved, rather than on the cause of the deaths avoided. In pretests we found that references to real-world programs such as Superfund cleanups and nuclear waste disposal caused people to focus on these aspects of the question rather than on the number of lives saved and the time at which they were saved.

Second, the question asks the respondent to

Maureen L. Cropper and Sema K. Aydede are an associate professor and a graduate student, respectively, at the University of Maryland. Cropper and Paul R. Portney are senior fellows at Resources for the Future.

The authors thank the National Science Foundation for its support under grant DIR-8711083.

This work has benefitted greatly from comments by Johnny Blair, Bill Evans, Sam Kotz, Robert Mitchell, John Mullahy, and Stanley Presser. The authors would like to thank Bill Evans for writing the computer program used to analyze the data.

put himself in the role of a social decision maker, rather than asking him to make decisions from a more selfish viewpoint. The fact that the respondent may benefit from Program A but not from Program B (depending on his age) may, however, influence his responses. We return to this issue below.

In analyzing responses to our question, we assume that the respondent receives utility $U_A = aX$ from Program A and $U_B = bY$ from Program B, and chooses Program A if

(1) $aX > bY$; which implies $b/a < X/Y$;[1]

where b/a is the fraction of a person saved today who is equivalent to saving one person at time T, or the marginal rate of substitution between lives saved today and time T.

We assume that there is a distribution of b/a values in the population, $F(b/a)$, and wish to estimate it. If b/a is a random variable, the probability that a randomly chosen person prefers Program A to Program B is

$$P(b/a < X/Y) = F(X/Y). \tag{2}$$

A simple way to estimate the distribution of marginal rates of substitution is to face n_i people with a given ratio of X/Y, $(X/Y)_i$, and to record the number of persons in cell i who favor Program A. The proportion of persons in the cell who favor Program A, p_i, is an estimate of the value of the cdf at $(X/Y)_i$ $F[(X/Y)_i]$. A nonparametric estimate of the distribution of (b/a) is obtained by plotting p_i against $(X/Y)_i$ for various $(X/Y)_i$ ratios.

Testing Discounting Hypotheses

In addition to examining the distribution of marginal rates of substitution for a given horizon, we are interested in seeing how these change as the horizon changes. Because the number of persons who must be saved at T presumably increases with T, the distribution of b/a should shift to the left as T increases. One hypothesis we are interested in testing is whether the distribution shifts in a manner consistent with constant exponential discounting. If people discount future lives saved at a constant exponential rate, the marginal rate of substitution between lives saved now and at T may be written

$$b/a = \exp(-\delta T); \tag{3}$$

hence, there is a one-to-one correspondence between the marginal rate of substitution b/a and the discount rate δ. The hypothesis that persons discount at a constant exponential rate can be tested by seeing whether the distribution of δ shifts with T.

Constant exponential discounting implies that the discount factor applied to a life saved at $T = 100$ to discount it to $T = 50$ is the same one applied to a life saved at $T = 50$ to discount it to the present ($T = 0$). The hypothesis that these two discount factors are equal has repeatedly been refuted in experiments involving the discounting of monetary payoffs (Horowitz, Lowenstein, Thaler, Winston and Woodbury). In terms of the present example, this literature has found that the discount factor used to discount lives from $T = 50$ to $T = 0$ is greater than the discount factor used to discount lives saved at $T = 100$ to $T = 50$, suggesting that the discount rate falls over time.

We examine the possibility that people discount lives saved at a nonconstant exponential rate by assuming that the discount rate δ declines linearly with time,

$$\delta(t) = \alpha - \beta t, \quad \alpha, \beta > 0. \tag{4}$$

This implies that b/a is of the form

$$b/a = \exp - \left[\int_0^T (\alpha - \beta t)\, dt \right] = \exp\left(-\alpha T + \frac{\beta T^2}{2} \right). \tag{5}$$

To capture heterogeneity in preferences, we assume that α is a random variable that is independently and identically normally distributed in the population with mean μ_α and variance σ_α^2; β, the slope of the discount rate function, is assumed identical for all persons. Given variation in T across respondents, μ_α, σ_α, and β can be estimated by maximum likelihood methods.

In addition to testing hypotheses about the discount rate, we wish to see how the mean of the discount rate function varies with respondent characteristics. Discount rates may increase with age if individuals consider benefits to themselves in choosing among life-saving programs. Individuals with small children may be more future-oriented (have lower discount rates) than

[1] We can allow for diminishing marginal utility of lives saved, i.e., $U_A = aX^n$ and $U_B = bY^n$; however, we cannot estimate n separately from b/a. Question 1 also prohibits estimating utility functions with an interaction term cXY. In written pretests of the questionnaire, however, we found that $c = 0$ and therefore abandoned more complicated questions (ones in which Program B saved lives today and at T) in favor of question 1.

those without, although people with children may consider it more important to protect their children when they are young than when they are old. Accordingly, we allow μ_α to depend on respondent characteristics.

Public Preferences for Saving Lives

The discounting results presented here are based on telephone surveys of households in Maryland, the District of Columbia, and northern Virginia conducted by the University of Maryland Survey Research Center.[2] In November 1990, approximately 1,000 Maryland households were asked questions similar to question 1. For half of the sample the time horizon for all questions was 25 years. For the other half, it was 100 years. A double-sampling strategy was used. Each respondent was asked which program he preferred, assuming that Program A saved X_1 lives and Program B Y_1 lives. Persons choosing Program A were randomly assigned a value of Y greater than Y_1 and asked to repeat their choices. For persons initially choosing Program B, the choice between the two programs was repeated with a randomly chosen value of Y less than Y_1. Respondents who selected the present-oriented program in both instances were asked the reason for their choice.

In March 1991, approximately 600 households in the Washington, D.C. area received questions similar to Question 1. A double-sampling strategy was again used. Each household was randomly assigned one of ten X/Y values and asked to choose between Program A and Program B, assuming Program B would occur in fifty years. The question was repeated, holding the X/Y ratio constant, with persons who chose Program A being confronted with a 25-year horizon and persons who chose Program B being confronted with a 100-year horizon.

Raw Data

Figure 1 shows the proportion of respondents in the Maryland Poll who favored saving lives in the present as a function of the ratio of lives saved in the present to lives saved in the future (X/Y). For each horizon, the proportion of those favoring the present-oriented program increases with X/Y. Furthermore, the proportion of those favoring the present-oriented program is higher, holding X/Y constant, the longer the horizon.[3]

Two features of the distributions are notable. First, when the number of lives saved at T is less than or equal to the number of lives saved today, about 10% of respondents still favor the future-oriented program: about 10% of our respondents have negative discount rates. At the other extreme, approximately 40% of the respondents choose the present-oriented program as X/Y approaches 0. There are two possibilities here. One is that while these invididuals may be willing to trade lives saved at T for lives saved in the present, they simply require more lives at T to switch to the future-oriented program than the maximum number in the survey.[4] The other possibility is that these individuals have lexicographic preferences: they would choose the present-oriented program no matter how many lives were saved in the future. One reason for this is the belief that technological improvements will enable future lives to be saved anyway—there is no need to make a trade-off.

To try to distinguish these responses, we asked persons who chose the present-oriented program (Program A) in both questions why they did so: 47% indicated that it was because "lives in the future will be saved some other way," suggesting that they would always choose to save lives today. We present results with and without these respondents, on the grounds that it is not meaningful to compute a marginal rate of substitution for persons unwilling to make trade-offs.

Further evidence of lexicographic preferences is provided by the Washington Poll. As indicated in appendix D (available from authors), the proportion of persons favoring the present-oriented programs in that survey remained virtually constant at .44 as the number of lives saved fifty years hence was increased from 1,000 to 15,000. To probe the reasons for this we asked persons who continued to choose the present-oriented program with $T = 25$ why they did so. Thirty percent said that improvements in technology would make it possible to save future lives as well as current ones, implying that it was unnecessary to make a trade off between

[2] A detailed description of the sampling strategies and survey instruments is contained in the appendices, available from the authors upon request.

[3] Although the two distributions cross at $X/Y = 0.9$, the null hypothesis that they are identical can be rejected (at the .05 level) in favor of the alternative hypothesis that the distribution for $T = 100$ lies to the left of that for $T = 25$ using the Kolmogorov-Smirnoff test.

[4] When $T = 25$, the maximum $Y = 4{,}000$; when $T = 100$, the maximum $Y = 7{,}000$.

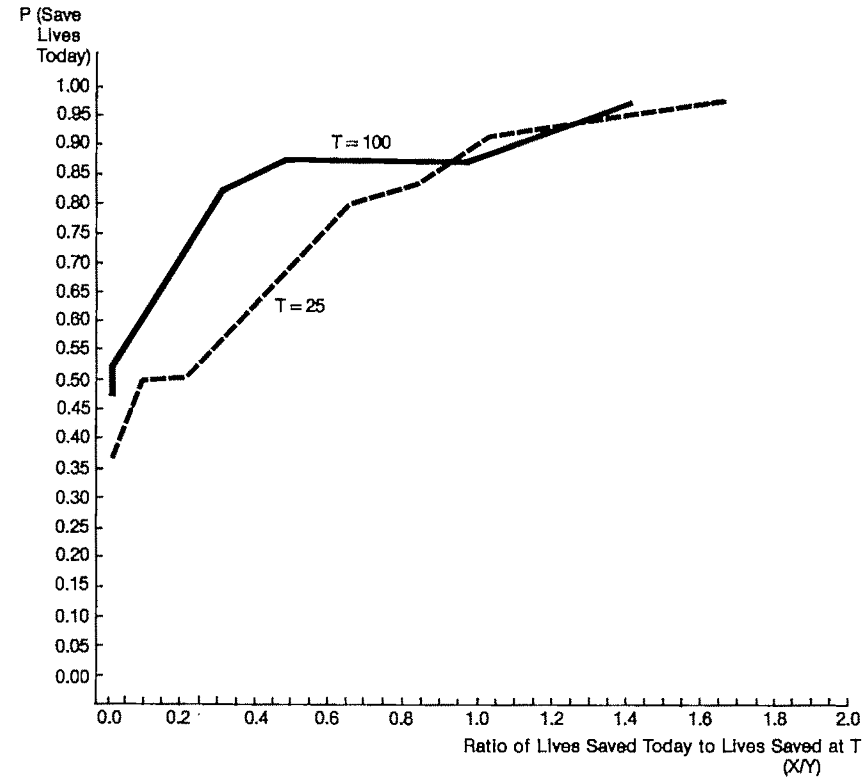


Figure 1. Ratio of lives saved

current and future lives saved. We report results with and without these responses.

Do People Discount at a Constant Exponential Rate?

Table 1 presents the discount rates implied by the Maryland and Washington Polls under the assumption that people discount future lives saved at a constant exponential rate. The mean and standard deviation of δ were estimated for each horizon, assuming that δ is normally distributed.

The results show clearly that the mean discount rate falls as the horizon increases: Based on all responses, the mean discount rate is approximately 8% for a 25-year horizon, 6% for a 50-year horizon, and 3% for a 100-year horizon. Tests of the equality of mean discount rates based on the assumption that δ is normally distributed allow us to reject the null hypothesis of constant exponential discounting.

We are also able to reject the hypothesis, proposed by Harvey, that people discount lives at a constant relative rate. According to Harvey's hypothesis, the factor applied to lives at T_2 to discount them back to T_1 is

$$b/a = (T_1/T_2)^r, \tag{6}$$

implying that the discount factor used to discount lives saved from $T = 100$ to $T = 50$ will be identical to the discount factor used to discount lives saved from $T = 2$ to $T = 1$.

To see exactly how fast discount rates fall over time, we estimated the model of equations (4) and (5), in which the yearly discount rate falls linearly. The results of estimating this model for the Maryland and Washington polls are presented in table 2. Examining the models without covariates, the mean discount rate is 8.7% in year 0, 5.2% in year 50, and 1.7% in year 100. If persons who believe that future lives will be saved some other way are removed from the analysis, $\delta(0) = 7\%$, $\delta(50) = 3.5\%$, and $\delta(100) = 0\%$. We consider the implications of these results in the conclusions.

Heterogeneity in Discounting Behavior

Our emphasis thus far has been on mean discount rates. Table 2, however, shows that there is considerable heterogeneity in discount rates.

Table 1. Parameters of Discount Rate Distributions Assuming Constant Exponential Discounting

Model	Length of Horizon 25 years	50 years	100 years
δ Normally distributed (all respondents)			
Mean of δ	.086	.068	.034
	(19.0)	(11.4)	(21.5)
Standard deviation of δ	.083	.092	.026
	(15.3)	(6.51)	(13.7)
N	462	528	442
δ Normally distributed (some respondents deleted)			
Mean of δ	.065	.053	.027
	(16.1)	(9.01)	(19.9)
Standard deviation of δ	.070	.097	.022
	(16.1)	(5.78)	(14.1)
N	371	451	341

Source: Maryland poll (T = 25 and T = 100); Washington poll (T = 50).
Note: $|t\text{-statistics}|$ appear in parentheses.

Table 2. Estimates of Discount Rate Function $\delta(t) = \alpha - \beta t$, $\alpha = X'\gamma$

	All Respondents	Some Respondents Deleted
μ_α	0.087	0.070
	(21.0)	(18.6)
β	7.12E-4	6.82E-4
	(5.24)	(5.34)
σ_α	0.062	0.052
	(23.3)	(25.3)
N	904	712
γ_0	0.065	0.053
	(5.87)	(5.65)
Age (years)	7.17E-4	7.10E-4
	(3.86)	(4.60)
Male	−1.98E-4	−3.56E-3
	(0.03)	(0.77)
Children ≤ 18 at home	0.015	8.66E-3
	(2.56)	(1.71)
White	−0.029	−0.031
	(4.59)	(5.88)
College degree	2.01E-3	3.19E-3
	(0.34)	(0.61)
Married	5.88E-3	4.21E-3
	(1.05)	(0.85)
Income ≤ $30,000	−1.84E-3	5.00E-3
	(0.29)	(0.90)
β	6.72E-4	6.34E-4
	(4.68)	(4.86)
σ_α	0.061	0.050
	(22.3)	(24.1)
N	794	628

Source: Maryland poll.
Note: $|t\text{-statistics}|$ appear in parentheses.

The standard deviation of α, the intercept of discount rate function, is almost as large as the mean, indicating substantial heterogeneity in beliefs. The mean discount rate also varies substantially with respondent characteristics. In all cases the discount rate is higher for nonwhite respondents than for whites, and higher for older respondents than for younger ones. Respondents with children under the age of 18 also have higher discount rates than persons who do not.

Each of these results seems reasonable. That blacks have higher discount rates than whites has been found by other researchers (Leigh; Kurtz, Spiegelman, and West). We note that this result is robust to the inclusion of income in the discount function and interpret it as reflecting shorter planning horizons for blacks than for whites. If the likelihood of benefiting personally from a life-saving program influences responses, then it is reasonable that older persons would discount future lives saved more heavily than younger persons. This is also reasonable behavior for persons with children, assuming that they are more concerned with their children's welfare as children than as adults.

What is perhaps surprising is that income (income ≤ $30,000) and education (college degree) have no effect on the discount rate. Recall, however, that what is being discounted here are anonymous lives saved. There is no compelling reason why low-income persons, who have been found to discount monetary rewards more heavily than high-income persons (Hausman, Lawrance), should discount anonymous lives at a higher rate.

Conclusion

The results we have presented focus on choices between life-saving programs over long horizons: 25, 50, and 100 years. One of our most striking findings is that, over horizons as long as these, a significant share of respondents seems unwilling to choose any future-oriented program, primarily because they feel society will find a way to save people in the future anyway. Along with confidence in technological progress, respondents who wanted to save lives today cited uncertainty about the future as a reason for being present oriented.

Even if we eliminate respondents who feel that it is unnecessary to make a trade-off between lives saved today and in the future, discount rates for life saving seem high: Assuming constant exponential discounting, the mean discount rate is 6.5% for a 25-year horizon and 2.7% for a 100-year horizon. This finding also reflects the fact that people do not discount at a constant exponential rate, a finding consistent with results obtained by Thaler and others in the context of discounting monetary payoffs. If discount rates are computed under the assumption that they vary with time, the mean annual discount rate is 7% today and 0% in 100 years (after eliminating the "have-their-cake-and-eat-it-too" respondents).

For several reasons, our conclusions must be interpreted cautiously. First, our results were obtained during relatively brief telephone interviews, which may not be the best way to get people to think reflectively about difficult issues. Second, despite our probing in focus groups and pretests, we have not been able to explore in great detail why respondents answer the way they do.

In future work we intend to investigate this in more detail and also to explore people's discounting behavior over shorter horizons. In addition, we will examine individuals' preferences for saving persons of different ages, for example, 30-year-olds versus 60-year-olds. While such trade-offs are clearly difficult, public officials must make them all the time.

References

Harvey, Charles M. "Value Functions for Infinite-Period Planning." *Manage. Sci.* 32(1986):1123–39.

Hausman, Jerry A. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables." *Bell J. Econ.* 10(1979):33–54.

Horowitz, John K. "Discounting Money Payoffs: An Experimental Analysis." *Handbook of Behavioral Economics*, vol. 2B, ed. Stanley Kaish and Benjamin Gilad. Greenwich CT: JAI Press, 1991.

Jones-Lee, Michael W. *The Value of Life: An Economic Analysis*. Chicago: University of Chicago Press, 1976.

Kurtz, Mordechai, R. S. Spiegelman, and R. W. West. *The Experimental Horizon and the Rate of Time Preference for the Seattle and Denver Income Maintenance Experiments*. Stanford CA: Stanford Research Institute Occas. Pap., Nov. 1973.

Lawrance, Emily C. "Poverty and the Rate of Time Preference: Evidence from Panel Data." *J. Polit. Econ.* 99(1991):54–77.

Leigh, J. Paul. "Accounting for Tastes: Correlates of Risk and Time Preferences." *J. Post Keynesian Econ.* 9(1986):17–31.

Lowenstein, George. "Anticipation and the Value of Delayed Consumption." *Econ. J.* 97(1987):666–84.

Mishan, Ezra J. "Evaluation of Life and Limb: A Theoretical Approach." *J. Polit. Econ.* 71(1979):687–705.

Thaler, Richard. "Some Empirical Evidence on Dynamic Inconsistency." *Econ. Letters* 8(1981):201–7.

Winston, Gordon C., and Richard G. Woodbury. "Myopic Discounting: Empirical Evidence." *Handbook of Behavioral Economics*, vol. 2B, ed. Stanley Kaish and Benjamin Gilad. Greenwich CT: JAI Press, 1991.

A Classification Tree for Predicting Consumer Preferences for Risk Reduction

John K. Horowitz and Richard T. Carson

Economists have long been puzzled by differences in the implicit value of life that can be inferred from consumers' responses to different risks. Individuals appear to be willing to pay more to reduce the risks from pesticide residues on food, for example, than they are to reduce the risks from increased exposure to solar radiation resulting from depletion of the ozone layer. Attempts to explain these differences have often attributed them to psychological aspects of the risks, but so far most of the analysis has concentrated on defining the risk characteristics rather than on explaining preferences (Slovic, Fischhoff, and Lichtenstein). In this paper, we attempt to explain preferences for risk reductions using the attributes of the risky substances. How do attitudes depend on risk levels, costs of risk reductions, and other features of the risky situations?

The analysis is based on two surveys of members of local Parents-Teachers Associations (PTA) in which subjects were asked about their preferences for reducing the risks from a number of risky substances. We first characterize the substances by the numbers of deaths that might be prevented through a risk reduction program and test whether subjects prefer to maximize the number of deaths prevented given a fixed expenditure on risk reduction. If subjects do not prefer to maximize the number of deaths prevented, this suggests that they do indeed implicitly assign different values to risk reductions from different substances. Based on our survey results, we reject the hypothesis that subjects prefer to maximize the number of deaths prevented, given fixed expenditures.

The authors are, respectively, an assistant professor at the University of Maryland and an associate professor at the University of California, San Diego.

This research was supported under Cooperative Agreement CR-815437-01-0 with the U.S. Environmental Protection Agency.

The authors are indebted to Ann Fisher, Maureen Cropper, Ellen Post, and Barry Galef for helpful comments and to Yau-Yuh Tsay for research assistance.

Several explanations are plausible. First, subjects may believe that they personally either are more at risk from the substance than the general population or are likely to bear more of the costs of regulation than the average person. They may also not entirely trust cost and risk information that differs from their own prior beliefs (see Viscusi). Alternatively, subjects may care much more about particular psychological or idiosyncratic features of the risks, such as how familiar people are with the hazards or whether the risk is voluntarily assumed. This behavior is more difficult to reconcile with a cost-benefit type of model of optimal risk regulation.

To explore these issues, subjects were asked to assess the extent to which they feel personally at risk from the given hazards, and how effective they feel government actions or their personal actions would be in reducing risks. Their responses were then used to predict preferences for reducing risk. We also included dummy variables for each of the individual substances to capture the effects of any idiosyncratic characteristics not explicitly considered. The survey results are analyzed with a nonparametric technique know as CART (Classification And Regression Trees) from Breiman et al. This provides a simple and useful picture of preferences for risk regulation.

Survey I

The first survey was administered in early May 1990 to members of a Parents-Teachers Association in the Washington, D.C., area. Using members of the PTA allows us to survey a relatively large group of subjects that is more representative of the U.S. population than most accessible groups (e.g., students, League of Women Voters) at a low cost.

Preferences for risk reduction were elicited through the following question:

A. Suppose the government had designed programs to reduce risks from four of these substances. The costs and benefits of these programs are listed below.

The costs include both costs that individuals would have to pay, and costs to the government. The benefits are given in terms of the number of deaths per year that could be prevented. Which substance do you think is most important to have the risk-reduction program for? Rank the substances from 1 to 4. Give a rank of 1 to the substance that you think it is most important to have the risk-reduction program for. Give a rank of 4 to the substance that you think it is least important to have the risk-reduction program for. Don't give the same rank to two different substances.

____**PCB in drinking water.** The proposed program would cost about $10 million per year and could prevent about 12 deaths per year.

____**Pesticide residues on foods.** The proposed program would cost about $10 million per year and could prevent about 5 deaths per year.

____**Radiation from the sun from use of CFC's.** The proposed program would cost about $10 million per year and could prevent about 8 deaths per year.

____**Automobile exhaust.** The proposed program would cost about $10 million per year and could prevent about 7 deaths per year.

There were five different versions of this question, each with the same four substances and the same four numbers of deaths prevented (5, 7, 8, 12) but with different pairings of substances and numbers of deaths. Each subject received one version only. The costs per death prevented in the version given above are $0.83 million, $2.00 million, $1.25 million, and $1.43 million, respectively. These costs reflect ballpark figures of the total economic cost of risk-reduction programs in general but not necessarily for specific risk-reduction programs for these four specific hazards.

The null hypothesis is that subjects prefer to maximize the number of deaths prevented, implying that the answer to this question for the version given above is the ranking: 1, 4, 2, 3.

Only nineteen out of ninety-four subjects chose the hypothesized ordering, and we reject the null hypothesis. (Details of the survey and the statistical results mentioned throughout the paper are available in Horowitz and Carson.) The finding that so few subjects preferred to maximize the number of deaths prevented is very striking, particularly because the tradeoff between deaths is so explicit in the set-up of the question. It suggests that idiosyncratic attributes of the risks themselves may play potentially large roles in consumer attitudes toward risk reduction.

To explore some of the possibilities, subjects were also asked to evaluate the following attributes for each risky substance: extent of exposure in the United States, potency, environmental effects, personal effectiveness in reducing risks from the substance, government effectiveness in reducing risks from the substance, number of current deaths attributable to the substance, number of future deaths attributable to the substance, and the extent to which the individual feels personally at risk from the substance. A total of eight substances was evaluated; see question B below for the list of substances.

The relationship between these attributes and the responses to question A was analyzed using a nonparametric technique known as CART. CART produces a classification or "decision tree" which uses a series of dichotomous splits of the data to predict the rank for each risky substance (see fig. 1). These dichotomous splits are based on the values of the explanatory variables. The explanatory variables in our analysis are the subject's evaluation of the eight attributes listed above (measured on a scale of 1 to 8) and the number of deaths prevented for the substance ("Deaths Prevented") as given in the subject's version of question A. The output of the classification tree is a set of predictions, such as "Pesticide residues on food will be ranked two," derived from a series of dichotomous splits of the form: "Is this one of the top two (out of eight) substances that caused the most deaths in the U.S. last year?" based on the individual's assessment of "Current Deaths."

CART is the most sophisticated of the general techniques available for ordinal (i.e., ranked) data with more than two levels of the dependent variable. It is particularly useful because it allows the response pattern between the dependent and independent variables to be different for different subsets of the data; for example, in tree A "Personal Risk" is an important attribute, roughly speaking, only if the "Future Deaths" rank is less than 3.5. It is flexible in allowing the researcher to incorporate different loss functions such as one in which underpredicting the rank assigned to a risk is considered worse than overpredicting the rank. Its primary disadvantage is that it does not exploit very efficiently the information from the subject's responses for one substance in predicting his responses for the other substances.

There are 92 complete responses. The 19 subjects who preferred to maximize the number of

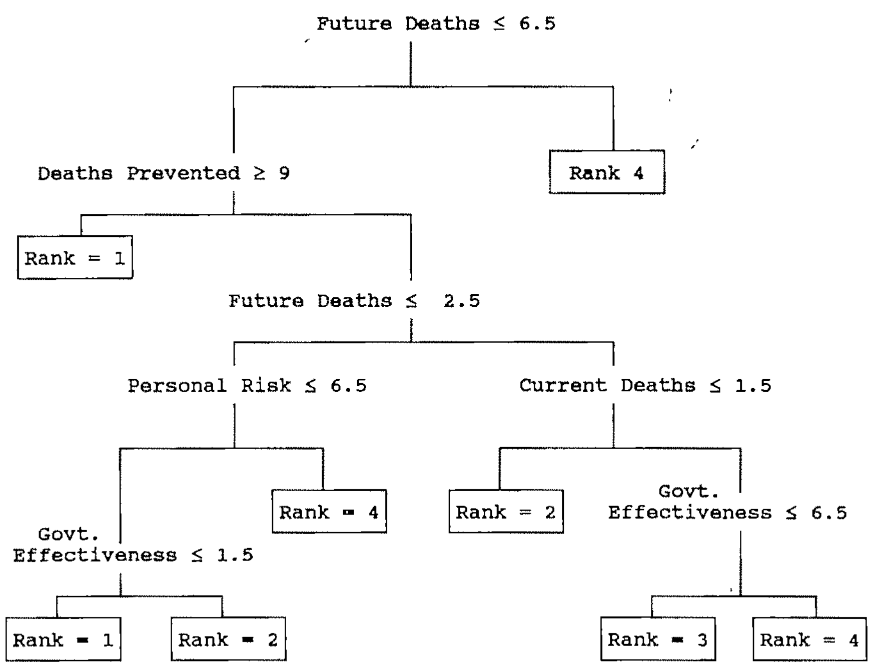
deaths prevented were not used in constructing the tree for the obvious reason that their responses can be predicted exactly on the basis of the number of deaths prevented. The tree generated from the remaining responses (tree A) is given in figure 1. Each observation consists of the rank assigned to one of the four substances by a subject (the dependent variable) along with his evaluations of the explanatory variables. There are evaluations of the four substances by 73 subjects, yielding a total of 292 observations.

Tree A first splits the observations according to the ranking on "Future Deaths": If the subject ranked a substance's "Future Deaths" between 1 and 6, go left; if it is ranked 7 or 8, go right. If the right branch is selected, the substance's rank in question A is predicted to be 4 and no further splits are made. But if future deaths were high and the left branch is selected, subsequent splits are made on the basis of the substance's "Deaths Prevented," then on the basis of "Future Deaths" again, and so on. The tree has eight terminal nodes. Notice that the splits at all of the decision nodes are in the expected direction; for example, if the personal risks from the substance are considered high (ranked closer to 1), the predicted rank in question A is also closer to 1.

To examine other potentially important substance-specific risk attributes, such as newness, dread, or voluntariness, a second classification tree (not pictured) was constructed that included dummy variables for each of the substances in the set of available explanatory variables. A prominent role for the dummies would indicate that characteristics other than those considered so far may be important components of risk attitudes, although it would not point out which specific omitted characteristics were most influential. However, there was no significant increase in the tree's predictive ability, and none of the decision nodes in this second tree was based on the substance dummies. This suggests that the more important features of the risks have already been identified and included in the analysis, at least for this particular set of substances.

Survey II

Further evidence on individual preferences for risk reduction comes from a second question that



A case goes left if the condition is true. All variables except Deaths Prevented are measured on a scale of 1 to 8 with 1 indicating more deaths, higher risk, or more effective government or personal actions.

Figure 1. Tree A

does not include explicit information about the number of deaths prevented. This is question B:

B. Suppose the government were going to spend $50 million per year to reduce risks caused by one of these substances. Rank order the substances from your first choice (give a rank of 1) to your last choice (give a rank of 8) for applying this money to.

____Radon
____Automobile exhaust
____Foodborne organisms
____Leaking Superfund sites
____Pesticide residues on foods
____Increased radiation from the sun from use of CFC's
____Shipping of chlorine
____Mercury from incinerators

Question B was administered to a second PTA group in September 1990. The responses are sets of ranks from 1 to 8 for 105 subjects. The mean ranks were 4.99, 2.78, 4.54, 4.07, 3.76, 4.13, 6.13, and 5.61, respectively. The strongest preference on average was for reducing risks from auto exhaust, followed by pesticide residues on food, leaking Superfund sites, increased radiation from the sun, foodborne organisms, radon, mercury from incinerators, and chlorine.

A tree for responses to question B, tree B1, is shown in figure 2. The potential right-hand-side variables (decision criteria in the tree) do not include the number of deaths prevented this time since none are provided in question B.

Trees A and B1 are remarkably similar despite the different formats and different subject groups. In both trees, attributes that measure the magnitude of the risks ("Future Deaths," "Personal Risk") are particularly prominent. Horowitz and Carson report that "Current Deaths" also appears as a predictive split in some of the classification trees they estimate. These results suggest that people may want the government to work to reduce the largest risks, possibly regardless of the actual reduction in risk that might be obtained.

The strong role played by the subject's perceived personal risk, "Personal Risk," likely occurs because not all subjects feel equally threatened by all substances, and they may prefer to reduce their own risks rather than to maximize the number of deaths prevented in society as a whole. The reason for "Future Deaths" importance may be similar; because the subjects were members of a PTA, most of them will have young children and can be presumed to see the items causing a lot of future deaths as a threat to their own households. Note that these assessments of personal risk levels and current and future deaths are entirely subjective and may not correspond

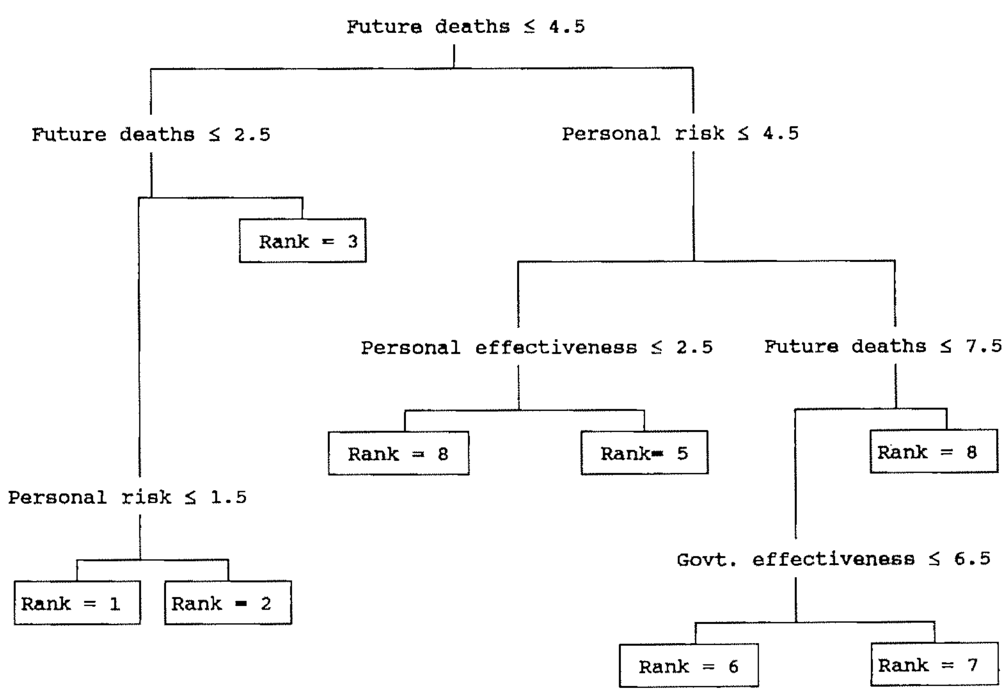


Figure 2. Tree B1

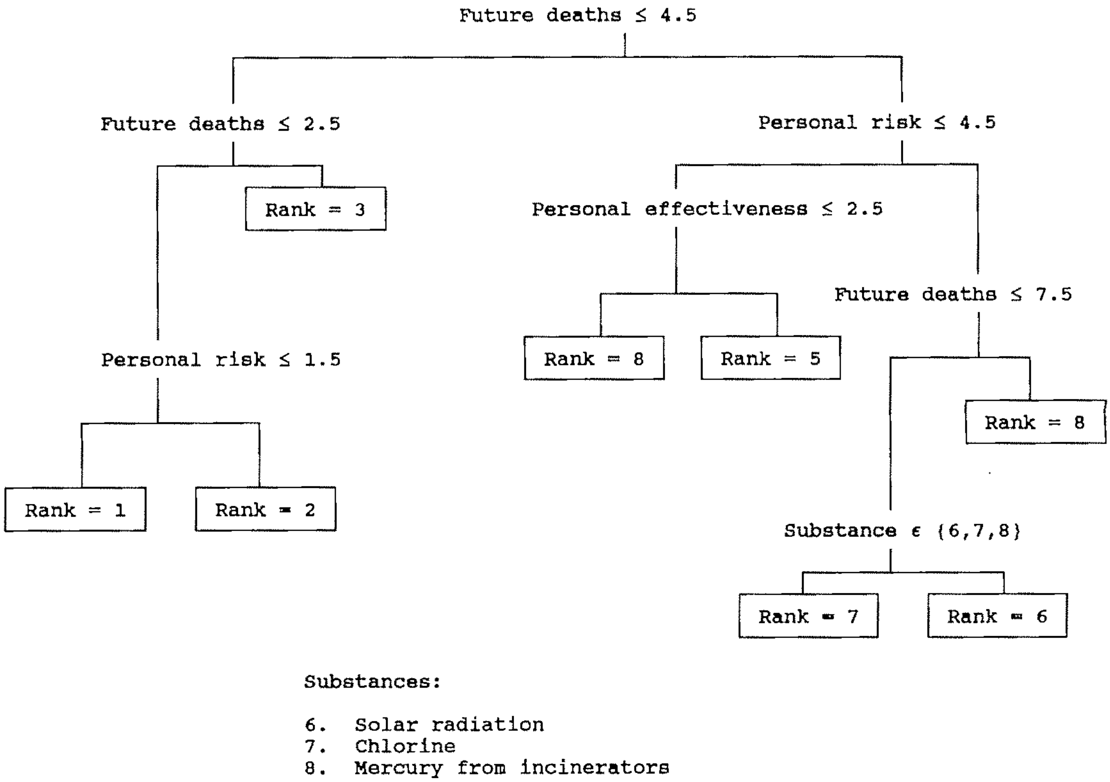


Figure 3. Tree B2 (includes substance dummy variables)

to the risk levels that scientists would calculate. Such perceptions may also be influenced by various attributes of the risks (e.g., Fischhoff et al.).

The other prominent variables in trees A and B1 are "Government Effectiveness," "Deaths Prevented" (in tree A), and "Personal Effectiveness" (in tree B1). Such findings make sense because subjects should prefer government actions to be directed where the number of deaths prevented is greatest or the government is most effective; this should be true even for those subjects who did not prefer to maximize the number of deaths prevented in all cases. People should also prefer projects where they cannot personally reduce risks very effectively.

The addition of substance dummies to the set of possible explanatory variables for question B yields tree B2 (fig. 3). Three substances (solar radiation, chlorine, and mercury from incinerators) are split from the other substances in the lowest branch of the tree. The tree is otherwise unchanged, and predicted mean rankings are not substantially altered from those of tree B1. An important question for future research is to determine what makes these three substances different from the others. It is interesting that the dummies show up as decision criteria only in the case where explicit risk information is not provided (question B) but not when such information is available (question A).

Concluding Remarks

Consumer attitudes toward health risks often appear difficult to explain. Our study suggests that risk preferences can be predicted using only a small number of attributes, including the number of deaths prevented, the perceived personal risk to subjects, the numbers of deaths attributable to the substance, and the effectiveness of government or personal action. Subjects appear to prefer to reduce those risks that threaten them most personally and for which government action is believed to be relatively effective. Subjects also appear to want to reduce risks that are expected to cause a lot of deaths in the future. Most subjects do not appear to prefer to maximize the number of deaths prevented in society as a whole, but this likely occurs because they believe that they are not affected by the risk or the regulations to the same degree as the general population.

In subsequent work we hope to explore these

issues further by including both a wider set of risk attributes and a wider set of risky substances.

References

Breiman, Leonard, Jerome Friedman, R. Olshen, and C. Stone. *Classification and Regression Trees*. Belmont CA: Wadsworth Publishing Co., 1984.

Fischhoff, Baruch, Paul Slovic, Sarah Lichtenstein, S. Read, and B. Combs. "How Safe Is Safe Enough? A Psychometric Study of Attitudes Toward Technological Risks and Benefits." *Policy Sci.* 9(1978):127–52.

Horowitz, John, and Richard Carson. *Do Consumers Really Care About Risk Characteristics?* Dep. Agr. and Resour. Econ., University of Maryland, 1991.

Slovic, Paul, Baruch Fischhoff, and Sarah Lichtenstein. "Characterizing Perceived Risk." *Perilous Progress: Managing the Hazards of Technology,* ed. C. Hohenemser, R. Kates, and J. Kasperson. Boulder CO: Westview Press, 1985.

Viscusi, K. "Prospective Reference Theory: Toward an Explanation of the Paradoxes." *J. Risk & Uncertainty* 2(1989):235–64.

Utility-Based Measures of Health

William N. Evans and W. Kip Viscusi

A large body of empirical work in economics seeks to determine how individuals value risks to life and limb (Viscusi, forthcoming). Most of this work has estimated premiums for job risks based on hedonic models of wage determination. Although there has been considerable debate in the literature regarding estimation of such models and selection of an appropriate implicit value of a statistical life based on these estimates, the scope of this debate is inherently limited. Market estimates can provide information only on the average rate of trade-off of income for risks. These trade-offs are also pertinent only to marginal changes in risk. Important policy questions, such as the benefits of nonmarginal changes in risks or the benefits of risk reductions in heterogenous populations, cannot be adequately explored with results from market settings.

The increased availability of survey data has brought these and many other questions regarding individual valuation of health risks within the range of answerable inquiries. In a standard survey setting, consumers are faced with a series of hypothetical choices for which subjects give a probability or an income value that makes them indifferent between the lotteries. An essential feature of experimental data is that surveys can be constructed to provide information on multiple points on a constant expected utility locus rather than a single point, as with market data. The points along the same locus will allow us to estimate the underlying structure of utility when utility depends on health. The key advantage of using such estimates is that it greatly broadens the scope of economic inquiry beyond the simple marginal income-risk trade-off one finds in the hedonic wage literature.

In this paper, we will explore the implications of some recent advances in the estimation of state-dependent utility functions for evaluation of health outcomes. First, we briefly review the theoretical literature that indicates how ill health should affect utility. Second, we outline how, with standard survey data, one can utilize survey data to produce utility function parameter estimates. Finally, we illustrate the types of policy questions which can be answered with utility-based measures of health.

William N. Evans and W. Kip Viscusi are faculty members in the Departments of Economics at the University of Maryland and Duke University, respectively.

Modeling the Utility of Ill Health

Viewed in its most general form, one can treat health status as simply a component of an individual's utility function, where utility U is a function of income Y and a health state H_i. If there are n possible states of the world, each with an associated probability of occurrence P_i, and income is assumed to be a function of health status, then expected utility is defined to be

$$EU = \sum_{i=1}^{n} P_i \, U(Y_i, H_i). \tag{1}$$

To explore the economic consequences of changing health status, ideally one would like to obtain a continuous measure of health. Typically, we do not have sufficient information to construct such a measure. More likely, researchers have information on discrete events, such as the probability that a certain type of injury will occur. Frequently, health status is subsumed into the analysis by indexing the utility function by the state of nature. This choice of modeling forms the basis for analyses of state-dependent utility. The state-dependent form of utility has been used extensively for risks to health, as in the work of Zeckhauser, Phelps, Arrow, Cook and Graham, and Spence.

To incorporate the dependence of utility on the health state, let state 1 be defined as perfect health with utility $U(Y)$. In the remaining $(n - 1)$ states of nature, the individual suffers some ill health. Let $V_i(Y_i)$ be utility in each poor health state i. With state-dependent utility, expected utility is now defined as

$$EU = P_1 \, U(Y) + \sum_{i=2}^{n} P_i \, V_i(Y_i). \tag{2}$$

Economists generally postulate the natural assumption that $U(Y) > V_i(Y)$. Assuming good

health is preferable to ill health simply recognizes that health is a valued economic good. A more troublesome issue is how ill health affects the marginal utility of income.

The theoretical literature typically assumes that for catastrophic events, ill health lowers the marginal utility of income, where for some fixed level of income Y in each state, $U'(Y) > V_i'(Y)$. In the extreme case of death, this assumption is clearly the case. However, for more minor injuries, ill health may be tantamount to a drop in income, i.e., for each poor health state i, the utility effects of poor health are equivalent to a drop in income of L_i dollars. In this instance, utility in the unhealthy state is defined as $V_i(Y) = U(Y - L_i)$, where L_i is defined as a "monetary loss equivalent." In this instance, poor health lowers utility but increases the marginal utility of income.

Determining how ill health affects the marginal utility of income is of paramount importance in answering a number of policy questions. For example, if ill health lowers (raises) the marginal utility of income, less (more) than full insurance is optimal. The optimal level of disability insurance and court awards for injuries consquently hinge on this issue.

Estimating State-Dependent Utility Functions

The dominant focus of the empirical literature on risk-dollar trade-offs has been on estimation of wage premiums for job risks using hedonic models of wage determination. In the simplest hedonic wage models of workplace risk, jobs are assumed to vary along two dimensions: wages and risks. The wages a worker receives and the risk he faces are based on the tangency of the worker's expected utility locus with the market wage offer curve. The tangency of these two curves is depicted in figure 1. Hedonic wage studies of compensating differentials for job risks involve estimation of an average rate of trade-off for the equilibrium set of expected utility-wage offer tangencies. The information contained in market data for any particular worker is simply point A of figure 1. Without any additional information, one cannot make any inferences about the shape of the individual's utility function other than the slope of the expected utility locus at point A. For policy analysis the most one can do is determine the average value of a marginal change in risk for a population similar to this group of workers.

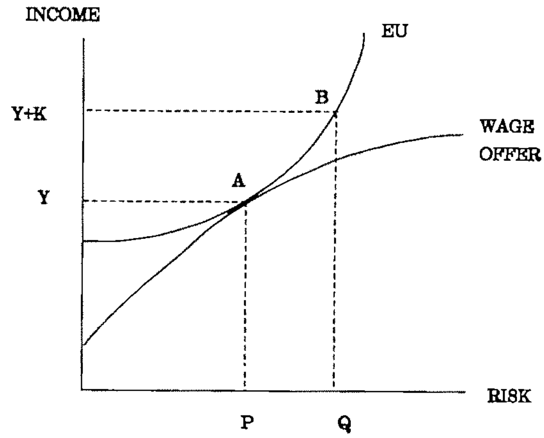


Figure 1. A worker's expected utility locus and wage-offer curve

Survey data provide a unique opportunity to estimate the state-dependent utility functions and the entire expected utility locus because the researcher observes multiple points along the same locus. In a typical setting, a "reference job" is introduced, where expected utility is a function of an original level of income Y, utility in the healthy state $U(Y)$, utility in the unhealthy state $V(Y)$, and the original risk of injury P. Next, the risk of injury is changed to some level Q, where in this case, we assume $Q > P$. Given the increased risk, the respondents are then asked how much additional income is required to compensate them for the increased risk of injury. The amount the consumer must be paid, K, is a value that equates expected utility across the two formulations of the job, where

(3) $EU_1 = EU_2$, or

$$(1 - P)\,U(Y) + P\,V(P)$$
$$= (1 - Q)\,U(Y + K) + Q\,V(Y + K).$$

The new information generated through the survey is depicted as point B in figure 1 along the original expected utility locus. As has been demonstrated in Viscusi and Evans, and Evans and Viscusi (1991a), parameter estimates of state-dependent utility functions can be derived once we assume an explicit functional form of utility. The estimation procedure is as follows.

Let β be a vector of utility function parameters to be estimated. The parameters in β are obviously a function of the assumed shape of utility. The response variable K is assumed to be the dependent variable since its value is conditioned on all others. Given a simple form of

utility (as in Viscusi and Evans), or utilizing a series of Taylor's-series expansions (as in Evans and Viscusi 1991a), the response variable K can be shown to be a nonlinear function of Y, P, Q, and β. An error term (ε) with zero mean and finite variance is then added to each equation and the model to be estimated is of the form

$$K = f(Y, P, Q, \beta) + \varepsilon. \quad (4)$$

Equation (4) can be estimated through nonlinear least squares; or in a limited number of instances, equation (4) reduces to a simple linear model.

We have estimated several variants of equation (4) for both major and minor injuries. In these models, we have varied not only the types of injuries but also the assumed functional form of utility.

Evidence from Workplace Survey—Viscusi and Evans

Using survey data from Viscusi and O'Connor, we estimate the impact on the marginal utility of income from an on-the-job injury severe enough to cause at least one lost workday. That survey collected information from chemical workers in four different plants pertaining to their income, individual and job characteristics, and the risks of injury they face on the job. The reference job was therefore their present employment situation. Next, workers were given a warning label for one of the following chemicals that would replace the chemicals with which they currently worked: TNT, asbestos, chloroacetophenome (an agent that causes tearing), or sodium bicarbonate. Based on their reading of the warning label, workers were asked to assess their individual risk of injury if they had to work with the new chemical. In all instances where a worker was faced with an increased risk, the survey ascertained how much their wage must increase in order to make them indifferent between the new and old formulations of their job.

Using an unrestricted utility function based on a Taylor's-series expansion, Viscusi and Evans demonstrate that for injuries severe enough to generate a lost workday, the injury lowers the marginal utility of income in the ill health state. Based on these results, we then assume an explicit characterization of utility, where utility in the healthy state is $U(Y) = \alpha \ln[Y]$ and utility in the unhealthy state is $V(Y) = \ln[Y]$; where clearly if $\alpha > 1$, then ill health lowers utility and the marginal utility of income. For the full sample, we estimate that $\alpha = 1.077$ with a small standard error of 0.009. Estimates which vary by the type of warning label shown to the workers indicate that ill health lowers the marginal utility from 4% to 9%, which we demonstrate below, has fundamental consequences for issues such as the optimal level of insurance.

Evidence from Consumer Products—Evans and Viscusi (1991a)

Using a sample of data from Viscusi, Magat, and Huber, we also estimate the impact on utility of relatively minor injuries arising from the use of household chemical products. Consumers were asked to evaluate either a toilet bowl cleaner or an insecticide. The survey presented consumers with two different formulations of the product. The product formulations varied only along two dimensions: the risk of injury posed by the use of the product and the price. The products were fictitious, but the labels were professionally printed, and they appeared to be commercially sold brands. For each product, the interviewer identified two potential injuries that might result from the product's misuse. For subjects with children under the age of five, the types of injuries were eye burns and child poisonings for the toilet bowl cleaner and inhalations and child poisonings for the insecticide. For subjects without small children, the child poisoning risks were replaced by gassings for the toilet bowl cleaner and skin poisonings for the insecticide. Consumers were asked how much they were willing to pay for a safer product. The answers to these questions equate the expected utility for two product formulations, where respondents indicate their willingness to pay for several alternate reductions in risk. Because these survey questions defined four points along the same expected utility trade-off, we are able to estimate the structure of the utility function in greater detail than in Viscusi and Evans. In particular, this greater flexibility enables us to nest a monetary equivalent model of health effects within a state-dependent utility function so that both potential ramifications of ill health can be jointly determined.

Using this data set, we characterized utility in the unhealthy state as being a function of two parameters, where $V_i(Y) = (1 + \beta_i)U(Y - L_i)$. With this formulation of utility, if $\beta_i < 0$ and $L_i = 0$, consumers view the injury strictly from a health-state perspective, whereas if $\beta_i = 0$ and $L_i > 0$, poor health is simply tantamount to a

drop in income, which is a very special case of health state dependence.

Using three different utility functions (logarithmic, linear, and quadratic), we find that for the minor injuries considered, consumers treated the injury as simply a drop in income. The estimates for the monetary loss equivalent range from \$486 for a gassing injury caused by a toilet bowl cleaner to \$2,537 for a child poisoning from insecticide use.

Economic Implications of State-Dependent Utility

Knowing the shape of the utility function and how the monetary loss equivalent varies with income allows us to estimate a number of different values of policy interest. As with present estimates from market data, one can determine the implicit value of a statistical injury. In addition, one can also answer questions about the income effects on the value of an injury and the value of nonmarginal changes in the risk level.

The Implicit Value of a Statistical Injury

The fundamental issue for decision analysts in health and medical policy is what value one should place on reducing such risks. When analyzing policies designed to alter risks to life and health, the most useful metric by which to express this value is in dollars of compensation required per unit of risk. There are two measures frequently utilized in policy analysis which are expressed in this ratio. The first is the amount a consumer would pay for the certain elimination of a risk. The second measure is the amount consumers are willing to pay for marginal changes in risk ($\delta Y/\delta P$) given an expected utility locus. Using the formulation of expected utility expressed on the left-hand side of equation (3), the marginal valuation of a statistical injury is easily calculated as

$$(5) \quad Z = \frac{\delta Y}{\delta P} = \frac{U(Y) - V(Y)}{(1 - P)\, U'(Y) + P\, V'(Y)}.$$

In regressions of wages on workplace risks, the regression coefficient on the risk variable can be easily transformed to obtain an estimate of the local rate of trade-off $\delta Y/\delta P$. Consequently, the second formulation of the implicit value of injury has been the most frequently utilized estimate of the economic valuation of health.

Given an explicit characterization of utility, the implicit value of an injury based on equation (5) can also be calculated from survey data. For a lost workday injury, the logarithmic utility function estimates indicate that the implicit value of an injury is \$13,343 in 1982 dollars. This number is very similar to estimates of the implicit value of an injury obtained from market studies of nonfatal workplace injuries (Viscusi, forthcoming).

When utility in the unhealthy state is tantamount to a drop in income, as it is for eight minor injuries we consider in the consumer products data set, the implicit value of a statistical injury is always within 1% of the estimated value of the monetary loss equivalent. This is not surprising given the small probablility of an injury and the relative size of L_i in comparison to Y. To see this formally, let $V(Y) = U(Y - L)$, where L is the monetary loss equivalent. These expressions are then inserted into equation (5), and the size of the derivative $\delta Y/\delta P$ is a function of the values for $U(Y - L)$ and $U'(Y - L)$. If we approximate $U(Y - L)$ and $U'(Y - L)$ with a second-order Taylor's series about Y and assume the third derivative of utility with respect to income is zero, these approximations produce the following approximation for the derivative:

$$(6) \qquad \frac{\delta Y}{\delta P} = L\,\frac{U'(Y) - (L/2)\, U''(Y)}{U'(Y) - (PL)\, U''(Y)}.$$

In many instances, Y is defined as yearly income and, therefore, for most utility functions, the second derivatives are small relative to the marginal utility of income. The ratio $[U'(Y) - (L/2)U''(Y)]/[U'(Y) - (PL)U''(Y)]$ in equation (6) is consequently close to 1, and the derivative $\delta Y/\delta P$ is close to L.

The above definition of the derivative $\delta Y/\delta P$ also suggests that if one assumes declining marginal utility of income, the estimate of the ratio $[U'(Y) - (L/2)U''(Y)]/[U'(Y) - P\,L\,U''(Y)]$ from equation (6) will be greater than one for $P < 1/2$. In most situations dealing with risks to health, P tends to be small and, therefore, the estimated value of the derivative $\delta Y/\delta P$ should be greater than the value of the estimated monetary loss equivalent. The difference in the two values will increase (decrease) as the value of L increases (declines).

The Value of Nonmarginal Risk Changes

Many government policies designed to reduce the risks to life and health produce more than

marginal changes in risks. Examples of such regulations are mandatory child restraint and seat belt use laws. In these instances, benefit-cost analysis becomes difficult with present value of statistical life estimates based solely on valuations of incremental risk changes.

However, with utility-based values of health, the analysis is easily conducted. In the survey setting outlined for equations (3), workers respond with income value K for a given increase in risk to Q. Using the parameter estimates for the utility functions in ill and good health, we can easily construct predicted values for K for any given change in the risk level.

Using the mean values of worker characteristics and the full sample estimates of the state-dependent utility functions found in Viscusi and Evans, we can verify a number of theoretical predictions about the value consumers place on nonmarginal risk changes. For example, the amount consumers must be compensated for a nonmarginal increase in risk increases at a declining rate, whereas workers are willing to pay successively smaller amounts for additional risk decreases. Both these results are predicted in the theoretical literature (see Viscusi, Magat, and Huber).

The ability to measure the value of nonmarginal changes in risk also allows us to illustrate the vast difference between a consumer's willingness to pay for a reduced risk and the willingness to accept a higher risk. First, consider a worker who faces a certain risk of injury on the job. This worker is willing to pay \$9,300 for the certain elimination of the risk. However, a worker in a risk-free job must receive over \$21,000 to be moved to a job with a certain risk of injury. Even in cases where the change in risks is not as dramatic, we still observe differences between the willingness to pay and accept. Consider a worker with a yearly risk of injury of 0.15 (about twice the size of the sample risk). The implicit value of an injury for the complete elimination of the risk is \$11,400, while the implicit value from a doubling of the risk is \$14,500. In both cases, the magnitude of the risk change is identical, yet the implicit values of the statistical injury are very different.

When utility in the unhealthy state is tantamount to a drop in income, as it is for the eight minor injuries we report, the implicit value of a statistical injury based on marginal changes in risk is very similar to estimates based on nonmarginal changes in risk. Again, this is not a surprising result given the small stakes. These results are reviewed in Evans and Viscusi (1991a).

The Income Elasticity of the Value of an Injury

Individuals differ in their attitudes toward health risks just as their preferences for other goods differ. This heterogeneity has two principle implications for public policy decisions affecting risks to life and health. First, the appropriate values of life and health will vary with the characteristics of the population at risk. Second, many of the differences are systemic. The primary concern in the economic literature has been with variations resulting from differences in wealth. If safety is a normal economic good, then individual risk-dollar trade-offs should be an increasing function of income, as shown in Viscusi (1979).

Using the definitions of the implicit value of an injury outlined in equation (5), we can calculate the income elasticity of the value of an injury for both the health-state and monetary loss equivalent cases. The explicit equations defining these values are found in Viscusi and Evans. When injuries are evaluated from a health-state perspective, we find that the income elasticity of the value of reducing risks of job injury is about 1.0.

When the unhealthy state is equivalent to a reduction in income, the values of the income elasticities are lower if the monetary loss equivalent if not a function of income. In a recent paper (Evans and Viscusi 1991b), we find that for the minor injuries considered above, the monetary loss equivalent values are indeed a function of income, and therefore the income elasticities of the implicit value of injury range from 0.17 for eyeburns from toilet bowl cleaners to 0.38 for skin poisonings from insecticide.

The size of the income elasticities that we estimate for the monetary loss equivalents and the marginal willingness to pay for safety are equal in magnitude to income elasticities for medical insurance estimated by Newhouse and Phelps but are substantially smaller in magnitude to elasticities estimated in Viscusi and Evans. The larger values in Viscusi and Evans stem from the difference in the structure of the utility functions for these more severe injuries, which differed by more than a monetary loss equivalent in the case of a job injury.

There are a number of contexts where knowledge of the income elasticity of the value of injuries is useful. Government programs, for example, have differential impacts on the health of different groups. Moreover, these groups may have a different mix from the sample of workers used in establishing the value-of-injury refer-

ence point. In cases where an attempt is made to assign a value to the risk reduction benefits based on the individual's own valuation of the risk, the income elasticity estimates can be used to establish the magnitude of such variations.

Making such distinctions across income groups may be less controversial in intertemporal contexts. Suppose, for example, that we have a choice between preventing an injury of fixed duration to a person now or a person ten years from now when his income will have doubled. This problem arises frequently in policy contexts, although not in as stylized a fashion. For example, the EPA must choose whether to focus its efforts on imminent hazards, carcinogenic or toxic exposure with a gestation period of one to two decades, or longer-term risks, such as changes in the earth's climate. Apart from the role of discounting, should we place the same value on health in each of these situations?

The conventional approach applied by government agencies is not to make any distinction. In fact, most government agencies that address long-term hazards have been reluctant to perform such discounting because it reduces the present value of the benefits substantially. However, the same forces that lead to a rationale for discounting also create the need for increasing the value of health losses as well.

Suppose that the growth in societal income is g and that the riskless rate of discount is r. One would expect $g < r$ because factors such as productivity growth resulting from capital investments rather than labor will induce some spread between societal income growth rates and interest rates. If the present implicit value of a statistical injury is denoted as Z, and the income elasticity of this value is close to 1, then in t years, the value of the injury will be $Z(t) = Z[(1 + g)/(1 + r)]^t$. Clearly, in this instance the loss in the benefit calculation because of the delayed nature of the benefits is at least partially offset by the growth in Z caused by an income effect.

Conclusion

The growth in the use of survey data in economics has greatly expanded the scope of questions one can consider when analyzing how consumers value risks to life and health. Experimental data has the unique property that through the construction of the survey, researchers can observe multiple points along the same expected utility locus. Given an explicit characterization of utility in the healthy and unhealthy states of the world, the researcher can then estimate the entire structure of utility.

Knowledge of more than the local rates of trade-off is important in a variety of policy contexts. The risk changes may be nonmarginal. The baseline risk level and the income levels of those affected may differ from the sample of individuals used to estimate the value of health outcomes. Knowledge of utility functions enables one to make the extrapolations necessary for health benefit assessment.

References

Arrow, K. J. "Optimal Insurance and Generalized Deductibles." *Scandinavian Actuarial J.* Reprinted in *Collected Works of Kenneth J. Arrow: Volume 3: Individual Choice Under Certainty and Uncertainty.* Cambridge MA: Harvard University Press, 1984.

Cook, P. J., and D. A. Graham. "The Demand for Insurance and Protection: The Case of Irreplaceable Commodities." *Quart J. Econ.* 91(1977):143–56.

Evans, W. N., and W. K. Viscusi. "Estimation of State Dependent Utility Functions with Survey Data." *Rev. Econ. and Statist.* 73(1991a):94–104.

——. "Wealth Effects and the Value of Health." Dep. Econ. Work. Pap., University of Maryland, 1991b.

Newhouse, J. P., and C. E. Phelps. "New Estimates of the Price and Income Elasticities of Medical Care Services." *The Role of Health Insurance in the Health Services Sector,* ed. R. Rosett, pp. 261–313. New York: National Bureau of Economic Research, 1976.

Phelps, C. E. *The Demand for Health Insurance: A Theoretical Perspective.* Santa Monica CA: Rand Corporation, 1973.

Spence, A. M. "Consumer Misperceptions, Product Failure, and Producer Liability." *Rev. Econ. Stud.* 44 (1977):561–72.

Viscusi, W. K. *Employment Hazards: An Investigation of Market Performance.* Cambridge MA: Harvard University Press, 1979.

——. *Fatal Tradeoffs: Public and Private Responsibilities for Risk.* New York: Oxford University Press, forthcoming.

——. "Wealth Effects and Earnings Premiums for Job Hazards." *Rev. Econ. and Statist.* 60(1978):408–13.

Viscusi, W. K., and W. N. Evans. "Utility Functions That Depend on Health Status: Estimates and Economic Implications." *Amer. Econ. Rev.* 80(1990):353–74.

Viscusi, W. K., W. A. Magat, and J. C. Huber. "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks." *Rand J. Econ.* 18(1987):465–79.

Viscusi, W. K., and C. J. O'Conner. "Adaptive Responses to Chemical Labeling: Are Workers Bayesian Decision Makers?" *Amer. Econ. Rev.* 74(1984):942–56.

Zeckhauser, R. J. "Medical Insurance: A Case Study of the Tradeoff Between Risk Spreading and Appropriate Incentives." *J. Econ. Theory* 2(1973):10–26.

Evaluating Programs That Save Lives: Discussion

Eileen van Ravenswaay

The three papers in this session illustrate how innovative survey research methods can be used to improve understanding of people's perceptions, preferences, and choices about health risks. This type of research is critical to improving the accuracy of estimates of the benefits of public programs that reduce human health risks. This research also produces behavioral information that is more likely to be relevant to policy makers than benefit estimates alone.

For example, the Evans and Viscusi paper discusses how the impact of health risk on utility varies with the severity of the health symptoms involved. They find the effect of minor injuries on utility is similar to a drop in income, whereas more serious health problems reduce the utility of income in the unhealthy state. Psychologists have often pointed out that the severity or dread associated with a health risk is important to people's risk acceptance (Slovic). Evans and Viscusi offer an economic interpretation of how changes in the severity of a health risk could be expected to affect risk acceptance.

The Evans and Viscusi paper also illustrates the importance to risk valuation of the baseline level of risk. Because the marginal utility of income declines with more severe risks, higher levels of initial risk will produce higher marginal valuations of risk reduction. This gives an economic explanation for the results reported in the Horowitz and Carson paper that people's preferences for risk reduction are affected by the total number of deaths attributed to a particular hazard. It also provides a partial economic rationale for the commonly made argument that government should focus resources on reducing the largest risks, such as smoking and drunk driving, assuming, of course, that the costs of risk reduction are similar across different sources of hazard.

Evans and Viscusi also point out that the direction of risk change matters. The state-dependent utility model predicts that people require greater compensation for accepting a risk increase than they are willing to pay for an equivalent risk reduction. This provides an economic interpretation of why the public seems to be more concerned about the added risks from manmade technologies (e.g., pesticides in food) than naturally occurring risks (e.g., bacteria in food).

Survey methods also provide a way of observing preferred choices about health risks that may not be available in markets. For example, Cropper, Aydede, and Portney are able to observe how preferences for life-saving programs are affected by the timing of the health risk reduction. Their findings suggest that there is substantial heterogeneity among individual discount rates and that implicit discount rates vary with the timing of lifesaving.

The Evans and Viscusi paper offers an economic interpretation of why we should expect heterogeneity in risk preferences among different demographic groups, particularly by income. Because risks affect utility and the marginal utility of income, risk valuation will be affected by income level and income growth over time.

The income growth effect provides a possible explanation of why Cropper, Aydede, and Portney observe differences in the implicit rate of discount for different timing of lifesaving. They find that the discount rate appears to be lower for programs with longer horizons. Similarly, Evans and Viscusi report that the income growth effect partially offsets the discount effect. The observed decline in the rate of discount may reflect expectations about the rate of growth in income.

A particularly interesting finding in the Cropper, Aydede, and Portney paper is that their sample had very high implicit discount rates. Those respondents who heavily discounted the benefits of future life-saving program reported that technological improvements and uncertainty about the future led them to do so. This finding has important implications for benefit assessment. Economists typically take a *ceteris paribus* approach to evaluating benefits in the

Eileen van Ravenswaay is a professor of agricultural economics, Michigan State University.

future. However, the results in this paper suggest that a more optimistic scenario of future conditions may be in order. The finding also has implications for understanding people's attitudes toward different types of risks.

The Horowitz and Carson paper provides several insights about risk perceptions that are consistent with economic models of choice. For example, they find that the size of the risk matters most to predicting people's ranking of risks and that people care about the risks that they themselves are most likely to experience. The finding that both personal and population risks influence risk preferences has important implications for the design of contingent valuation surveys. Many contingent valuation surveys simply give respondents a population risk estimate and then ask them to evaluate reductions in that risk. The finding in the Horowitz and Carson paper indicates that this approach is invalid. Rather, people's own perceptions of the risk need to be considered as well.

The Horowitz and Carson paper also reports that preferences for risk-reducing programs were influenced by the cost of reducing a risk. While this finding is obvious to economists, it is a point often missed by others. For example, many people have said that the fact that people "overreact" to small risks like Alar in apples, but "underreact" to relatively large risks like radon shows that people "misperceive" risks. An alternative explanation for this pattern of response is that people pay attention to the cost of risk avoidance. Because there are many close substitutes for apples, the avoidance costs for Alar were quite small, but the avoidance costs for radon can be very high. This finding suggests that policies that permit balancing of benefits and costs may better reflect people's preferences than policies that do not (e.g., the Delaney Clause of the Food, Drug and Cosmetic Act).

Survey research by economists promises to yield a richer understanding of how people perceive and make choices about health risks. This development is important because this behavioral information is more likely to be relevant to policy makers than simple bottom line estimates of program benefits. In fact, policy makers have been very reluctant to accept simple monetary valuations of lifesaving programs. Such benefit estimates have been widely criticized as "putting a dollar value on life." However, policy makers seem to be receptive to findings about how people think about and react to health risks. It is not uncommon, for example, to hear policy makers talk about the importance of "risk characteristics," such as voluntariness and dread in understanding public concerns about health and environmental risks. This suggests economists should place less emphasis on dollar estimates of benefits and more emphasis on the factors affecting choices about risks. This will require more innovative survey work by economists.

Reference

Slovic, Paul. "Informing and Educating the Public About Risk." *Risk Analysis* 6(1986):403–15.

Evaluating Programs That Save Lives: Discussion

David Zilberman

The three papers raise valid issues and make good points. Each paper offers some unique insights, and they complement each other with regard to concern for consumer evaluation of lifesaving activities.

"Discounting Human Lives," by Cropper, Portney, and Aydede, demonstrates that it is very difficult to elicit accurate preferences regarding life-saving activities. People's choices reflect both their preferences and their beliefs about how the world works. Thus, people may prefer to spend more on programs that save lives now rather than in the future not because they have low discount rates but because they believe that new lifesaving technology will be available in the future, or because they do not believe in the government's ability to keep its promises regarding the future.

The empirical findings again demonstrate that people's responses reflect self-interest, and options are considered in terms of possible personal impacts. One example of this that I find insightful and realistic is the finding that people with children have a much higher discount rate than the childless. Being a parent myself, I think this makes sense. The day-to-day pressures of raising a family force parents to emphasize the present. One general lesson from the authors' findings is that the more you worry about survival, the higher the interest rate.

Many of the findings are not consistent with the notion of rational behavior as dictated by economic theory. While many economists expect humans to perform like "A" students in economics, in reality they often perform like "C" students or worse. There are gaps between optimal and actual behavior which are important to understand and explain. And I believe this paper accurately detects these gaps.

"A Classification Tree for Predicting Consumer Preferences for Risk Reduction," by Horowitz and Carson, complements the previous paper because it tries to document how people actually make choices about lifesaving or health-improving activities. What they find is that actual behavior can be traced well by recursive models, and they confirm that people's behavior deviates substantially from what economic theory prescribes. Thus, it may be most helpful to develop two sets of models, one to describe and predict behavior and the other for normative analysis, rather than using the same framework for both.

One conclusion to be drawn from Horowitz and Carson's results is that responses depend in large part on people's beliefs and knowledge about particular risks. It is not so much preferences as perceptions that affect choices, and that may explain seemingly paradoxical choices. It is clear that it is important to educate people about risks at a young age. Exposure to the basic notions of toxicology, including the concepts of exposure and dilution, will enable people to make better choices.

The third paper, "Policy Analysis Using State-Dependent Utility Functions," by Evans and Viscusi, is an interesting attempt to use the much-maligned modified expected utility function for risk evaluation. Its use of state-dependent utility is realistic and practical. Utility is dependent not only on health status but also on other variables such as self esteem. In essence, when it comes to uncertainty, it is most useful to think in terms of a family production function, where people derive utility from certain characteristics including, for example, pain, fun, and personal fulfillment. Health and income help individuals to realize these characteristics.

It is important to recognize that individuals will regard injuries that affect performance or enjoyment over the long run differently than injuries from which they expect to recover. Evans and Viscusi deal with the second type of injury, and therefore, their expected utility model works very well. The challenge, both theoretically and empirically, is how to deal with injuries that are debilitating in the long run. And this is something which has not yet been addressed well.

David Zilberman is a professor, Department of Agricultural and Resource Economics, University of California, Berkeley.

Impacts of Structural Adjustment Programs on African Women Farmers and Female-Headed Households

Jean M. Due and Christina H. Gladwin

The structural adjustment programs (SAPs) initiated by the International Monetary Fund (IMF) and the World Bank and supported by donors are stimulating many tropical African economies through an infusion of foreign exchange, increased agricultural prices, devaluation of overvalued currencies, improved marketing policies, trade liberalization, and increased competition from the private sector. Recently, however, debates about the pros and cons of SAPs have ensued.

On one side of the debate are those who argue that underlying SAP prescriptions is the neoclassical assumption that markets work, markets are generally competitive, and undistorted market signals are good guides to resource allocation (O'Brien). Structural adjustment thus relies on more intensive use of the private sector through divestiture of nonstrategic public enterprises—parastatals—and requires the removal of exchange rate and other biases against exports or tradables and the switching of resources from the production of nontradables to tradables. It also demands the reduction of budget and balance-of-payments deficits through fiscal and monetary measures, as well as a public service that is efficient, reliable, with transparent accounting for public monies.

But as Elson (1989, p. 60) points out, adjustment means change, and change means costs as well as benefits, losers as well as winners. Who will be the winners and losers? The people who use imported goods—urban elites, industrial producers, agricultural implement users, truckers— will be losers unless domestic prices increase correspondingly because devaluation increases the cost of imported inputs. If devaluation is coupled with an increase in agricultural producer prices, farmers should benefit and urban consumers should lose. This should stimulate agricultural production in the long run, encourage import substitution of domestic goods in production, and diversify exports.

Does this happen in practice? A related question is: Are SAPs gender neutral (i.e., affecting men and women equally) or merely gender blind (i.e., ignoring the impacts on women and assuming them to be the same as on men)? The distinction between the two is critical in African countries where rural producers, who would supposedly gain from an urban-to-rural redistribution of income under SAP reforms, are women who provide 46% of agricultural labor, on average, and produce most of the food crops in many societies. In theory, SAP programs should benefit women producers because much emphasis is placed on renewing agricultural production and aligning farmgate prices with world prices.

This paper argues that women farmers, married and unmarried, and the 25% of the rural households in sub-Saharan Africa which are female headed, do not often benefit from SAP programs. SAP reforms have worsened the agricultural production and incomes of women farmers by being too macroeconomic in scope and ignoring the reality of life at the village and household level, where male-female power relationships affect who gets access to the means of production and who controls the surplus or profit that results from added incentives to produce. Because of inequality in gender relations and women's relative lack of power, women producers are not in a position to react with an economically appropriate supply response because they lack access to basic inputs of production that men farmers, especially large farm-

Jean Due is Emerita Professor of Agricultural Economics, University of Illinois; Christina Gladwin is a professor, Food and Resource Economics Department, University of Florida.

ers, have received: land, credit and fertilizer, labor, and even the right to returns from their own labor. Given SAPs' greater emphasis on tradables, men who tend to grow export crops may appropriate more of these basic inputs, including women's labor, from the women who grow food crops, making their job to feed the family more difficult and their opportunities to generate a marketable surplus even rarer. In addition, the consumption-oriented policies within SAP programs—reduced expenditures for health (including family planning) and education, in particular—have adversely affected female-headed and low resource households in both urban and rural sectors. Many of these households are forced to bear heavier burdens of food, education, and health costs and are locked into a permanent cycle of poverty.

This paper presents evidence supporting these arguments. Section 1 shows that women producers, especially female heads of households (FHHs), lack access to basic inputs of production, and this is reflected in lower production, incomes, and resources. Section 2 describes particular components of SAP reform packages which limit FHHs' ability to react to SAP incentives with an improved supply response. We conclude that SAP programs are not gender neutral in operation or effect, and complementary policies—credit, fertilizer subsidies, and income-generation programs for women farmers, nutritional supplementation programs for female-headed households, programs of debt forgiveness, and reduced defense expenditures for their governments—are needed to mitigate the adverse effects of SAPs on women farmers.

Inequality in Gender Relations

There is general agreement that African women provide most of the labor required to produce food crops in Africa; women's labor force participation rates are 46% on average (Dixon), with much regional variation (Boserup). There is no debate that the proportion of African smallholders who are female-headed households is high, at 25% to 35% (Due and White). Indeed, the only debate surrounds the questions of how gender affects development and why the supposedly gender-neutral SAP recommendations would be undermined by the gender of food producers whom they are supposed to help.

The answer lies in the reality of social stratification and differentiation at the village and household level and imbalances in power relations which affect who gets access to the means of production and who controls the surplus or profit that results from added incentives to produce tradables. Women's relative lack of power constrains them, not simply to reallocate their time differently between subsistence food crops (nontradables) and cash crops (tradables), but to increase, and sometimes double, their total hours of labor (Gladwin and McMillan). The WID literature more than adequately documents women's limited access to other modern yield-increasing inputs—seeds, fertilizer, credit, extension advice, technological training—that a switch of resources from the production of nontradables to tradables will demand (Fortmann, Staudt). A review of recent results comparing women-headed households and "joint" households with both a man and woman present (JHHs) will serve to put the question of SAP impacts in historical perspective.

Female-Headed Households

Female-headed households currently comprise 25% to 35% of both rural and urban households in most countries of tropical Africa and may be either *de facto* or *de jure*. A *de facto* FHH is one in which the husband is away for long periods of time, making it necessary for the wife to do the decision making and support the family, although there may be income coming from the husband irregularly from time to time. The wife makes decisions about family expenditures and farm operations when the FHHs are rural. A *de jure* FHH is one in which the head is divorced, widowed, or a single parent; in *de jure* FHHs the female head must make all decisions and support the family; polygamous households are excluded. Many persons argue that, in the extended family system in much of tropical Africa, *de jure* FHHs receive considerable counsel and assistance from the extended family. Yet, during personal interviews, women heading these households claim they are very much alone and are almost solely responsible for the welfare of their families.

There are major contrasts between FHHs and JHHs in rural areas when both types of households are farming. The major factor which differentiates these households is that FHHs, with no able bodied male (or additional adult female) present are smaller in size than JHHs and therefore have less labor available for agricultural production in a farming system that is very labor intensive. With less labor available, FHHs have

smaller crop acreages planted; this results in lower agricultural output, and a higher percentage of production is needed for family consumption, leaving less for sale. Therefore, average and per capita net incomes are lower. Also, FHHs have less access to credit for hiring labor or labor-saving devices and less access to extension services. FHHs plant different crops than JHHs, on average; more of their total crop acreage was allocated to food crops than that by JHHs. The provision of food is a high priority for both types of families; but, with smaller acreage planted by FHHs, it is important to allocate a greater percentage of their land to food crops. As shown in table 1, compared to JHHs, the Zambian females planted a higher percentage of their crop acreage to maize, the major food staple, and the Tanzanian FHHs to maize, beans, cassava, and other vegetables. These results are substantiated from 1982 studies in Zambia (Due and White; Sikaponde; Due, Sikaponde, and Magayane), in Tanzania in 1984 (Mollel), and in Zambia in 1986; see table 1, in which data were collected from samples of JHHs and FHHs in the same agroecological areas.

FHHs' Lack of Access to Inputs of Credit and Fertilizer

In Malawi, Gladwin found that, although 69% of full-time farmers are women, 50% of agricultural labor is performed by women, and FHHs comprise 28% of all households, women accounted for only 25% of credit club members in 1986/87. The disparity between women's participation in farming and in credit clubs is unfortunate and results from institutional barriers and social constraints. Few women farmers are full members of "farmers' clubs," which provide credit and extension advice, because by law, married women are automatic members, receiving credit indirectly through their husbands. The few women who are full members are unmarried women or women in a polygamous union whose husband is giving fertilizer to the other wife. They are there by necessity, because they do not have a man to be their intermediary. It is thus a social stigma rather than a privilege for these women to attend the farmers' club meetings, and they sit apart from the men, silent and embarrassed. The women are all too aware of

Table 1. Comparison of Joint-Headed and Female-Headed Farm Households in Zambia and Tanzania Studies

	Zambia 1982[a]		Tanzania 1984[b]		Zambia 1986[c]	
	JHH	FHH	JHH	FHH	JHH	FHH
Sample Size	95	17	118	32	97	27
Means of:						
Age	42	44	49	43	41	43
Family size	7.4	4.5**	NA	NA	NA	NA
Adult equivalents[d]	4.1	2.3*	NA	NA	3.5	1.7***
Acreage in crops	11.5	4.9*	2.7	1.4	6.8	3.0**
Maize	7.6	3.8*	1.7	0.8	5.4	2.4**
Beans	0.3	0.2	0.1	0.1	0	0
Groundnuts	0.9	0.3**	0	0	1.0	0.5
Cotton	1.2	0.2*	0	0	0	0
Sunflower	0.9	0.3	0	0	0.2	0
Others	0.6	0.1	0.9	0.5	0.2	0.1
Total value crop						
Production	K 1,201	K 368**	Ts 5,683	Ts 3,440	K 4,358	K 1,778**
Crop sales	K 763	K 139**	Ts 1,166	Ts 329	K 2,904	K 522**
Livestock sales	K 193	K 35*	NA	NA	NA	NA
Farm expenses	K 324	K 85	NA	NA	K 68	K 3.0**
Off-farm income and gifts	K 216	K 230	NA	NA	NA	NA
Net cash income	K 848	K 319	Ts 3,659	Ts 200*	K 2,836	K 1,775
% of families visited by extension agents	57	29	40	28	60	19**
% crops consumed	38	64	87	96	35	74

Sources: (*a*) Due and White, crop year 1982.
(*b*) Mollel, crop year 1984.
(*c*) Sikapande, crop year 1986.
(*d*) Adults available for farming; adult males and females equal 1.0, children aged 8–11 equal 0.3 and aged 12–17 equal 0.5 adults.
Note: Single asterisk indicates significant differences between means at $p \leq .1$; double asterisk indicates significant at $p \leq .05$; and triple asterisk indicates significant at $p \leq .001$; NA, not available, K is Kwacha, and Ts is Tanzanian shillings.

the loss of social status that full membership implies and would prefer to belong to a women's club of both married and unmarried women administered by Malawi's Women's Programme. Unfortunately, the number of women's clubs at the village level is few, and the amount of credit they now receive is minuscule, although their default rates are lower than those of the farmers' clubs. Also limiting the number of womens' clubs is the scarcity of female extension agents serving the Women's Programme. In 1985, there were 1,800 women farmers per female extension agent, as contrasted with only 461 male farmers per male extension agent. An additional constraint to FHHs' access to credit is their small farm (garden) size: almost half (42%) of the FHHs have farms of less than 0.5 hectares. And one of the criteria by which local farmers' clubs admit or reject members is a "reasonably sized garden," which varies from 0.5 to 2 hectares. Hence, almost half of FHHs are excluded from full membership in a farmers' club because of the small size of their land holding.

What is the impact of this gender bias in access to credit? Data in table 2 show that the total amount of fertilizer, the main yield-increasing input to cash and food crops, used by FHHs is half that used by JHHs; and the difference is very significant ($p = 0.0001$). Data also show that fertilizer per hectare used by FHHs is also significantly less than that used by JHHs at the 0.01 level.

But if access to credit and cash were also held constant, would gender have a significant direct effect on fertilizer use? Regression analysis is used to show that it does not: although women household heads apply uniformly less fertilizer per hectare than men heads, gender does not matter when one holds constant access to credit and cash. But without access to credit or cash, FHHs apply less fertilizer than men. Regression is not used here to show causality, merely the link between the quantity of fertilizer per hectare (*CFHA*) and five independent variables. These include the quantity of land cultivated (*AREA*), a dummy variable representing the farmer's participation in a credit club (*CURCLUB*1), a dummy variable which equals 1 if the farmer said his reason for nonuse of fertilizer was "insufficient money" (*NOCASH*), a dummy variable representing the gender of the farmer which is 1 if the farmer is a male, and a variable *CMANURE* representing application of manure/compost which may either be a substitute or complement for chemical fertilizer. The price paid by farmers for fertilizer is omitted because it is constant across Malawi as a result of monopsonistic control of ADMARC, the state marketing board. In fact, previous studies that tested for a price response have shown no significant effect of fertilizer price on quantity demanded and even found the wrong sign (Nyondo 1987).

Results in table 3 show that, as expected, access to cash and credit have very significant and positive effects on the quantity of fertilizer applied by an individual smallholder. The signs on the significant variables say that the cash constraint decreases fertilizer use significantly, but membership in a farmers' credit club increases it significantly. In addition, the positive sign on manure application shows it is a complement to chemical fertilizer in Malawi because soils need both chemical and organic fertilizers. The amount of land cultivated is linked negatively with the quantity of fertilizer per hectare. This is because the smaller the area cultivated, the more fertilizer is poured on, holding other variables (access to cash/credit) constant. The latter result is not a surprise when fertilizer comes as an indivisible input of 50-kilogram bags to most smallholders. Note that all variables except gender are highly significant ($p = 0.0001$). Gender thus has no direct effect on fertilizer use, but because FHHs lack access to both cash and credit, they apply less fertilizer than men.

Other data from Malawi show the impact of lack of equal access on incomes of FHHs, compared to JHHs. In Chipande et al.'s study of 600 farms, it was ascertained that FHHs were at the bottom of the income scale, lacked resources,

Table 2. Differences Between Male- and Female-Headed Households, Blantyre, Lilongwe, and Kasungu Districts, 1986/87

	Male Household Head	Female Household Head	*t*-Value	Probability
Number farmers	349	152		
Total fertilizer (kg)	72.41	30.24	5.18	0.0001
Fertilizer use (kg/ha)	51.28	34.41	2.29	0.011
Landholding size (ha)	1.33	0.80	7.84	0.0001

Source: Malawi Rapid Fertilizer Survey, 1987.

Table 3. Regression on Quantity of Fertilizer per Hectare (CFHA), Blantyre, Lilongwe, and Kasungu, 1986/87

Independent Variables	B	*t*	*p*-value
Intercept	100.97	12.37	0.0001
AREA	−0.19	−5.25	0.0001
*CURCLUB*1	36.33	4.50	0.0001
NOCASH	−85.99	−12.33	0.0001
GENDER	0.73	0.11	0.91
CMANURE	21.25	2.45	0.0146
Number	498		
F	57.79		
R-square	0.369		
Signif.*F*	0.0001		

Source: Malawi Rapid Fertilizer Survey, 1987.

and had average cash incomes of K166 of which 2% came from off-farm employment, 84% from the sale of agricultural products (local maize, groundnut, and pulses) and 14% from nonagricultural activities (beer brewing, selling processed food, fish, and handicrafts). Another Malawi study of 100 JHHs and 100 FHHs, carried out by Phiri, compared sources of household cash income and expenses of the two groups. They found that FHHs had 58% of the cash income of JHHs.

Negative Impacts of Structural Adjustment Programs on FHHs

It is now left to show that FHHs' ability to respond to improved price incentives or trade liberalization is limited or nonexistent because, as a result of inequality in gender relations, they lack access to basic inputs of production that men farmers receive: ownership of land (Goheen), credit and fertilizer (Gladwin), labor, even their own (Guyer with Idowu, Due and Magayane), and in many societies they lack the right to grow cash or export crops (Lele 1991). Given the SAPs' greater emphasis on tradables, men who grow export crops will tend to appropriate more of these basic inputs from the women who grow food crops, making their job to feed the family more difficult and their opportunities to generate a marketable surplus even rarer (Meena). The result may not be that men will take over more of the food production, at least not in the short run because, as Boserup (p. 34) has pointed out, men usually refuse to do work which according to prevailing custom should be done by women.

Elson (1991) agrees and claims that the sexual division of labor, which determines that some sorts of work are suitable for women but unsuitable for men, can thus present a barrier to the reallocation of labor—women's labor in Africa—from the production of nontradables to the production of tradables. The assumption that human resources can be treated as if they were costlessly transferable between different activities and different crops ignores sexual-division-of-labor rules which require African women to provision the household while men control export crop production. The failure of SAPs to give explicit consideration to gender differentiation and their treatment of labor as ungendered may mean that SAPs fail to achieve their objectives.

In this paper, we claim that SAPs, because they ignore gender differentiation at the village and intrahousehold level, impact negatively on women farmers. The question of impact really boils down to the question of how higher prices, designed to elicit an improved supply response, impact on women farmers. Unfortunately, the evidence is not totally unambiguous, as some studies do show a positive impact, such as Guyer with Idowu's case study of entrepreneurial Yoruba women who were encouraged to start their own farms and cash in on higher producer prices produced by the Nigerian ban on all imported food as part of its SAP program. Ensminger's case study of Orma sedentarized pastoralists, who produce meat but do not consume it, also shows that the rise in Kenyan meat prices during the 1980s has meant greater incomes, education, nutrition, health, and political power for Orma women. Are these the exceptional cases that prove the rule?

More studies show that higher producer prices can hurt FHHs, the smallest of the smallholders whose households are not usually self-sufficient in food production. Because they are net buyers rather than net sellers of food products, they suffer when food prices rise. How extensive are food-buying households in rural Africa? Peters and Herrera claim that less than 15% of Malawi's smallholders are fully self-sufficient in maize production. Lele (1989, p. 16) terms the structure of Malawi's agriculture a "dualism-within-dualism" structure, whereby the small farm sector is distinct from the large "estate"sector and smallholders are split into two groups: a minority who have a farm size large enough "to produce a marketable surplus and capable of taking risks and a preponderant majority experiencing stagnation or near economic paralysis." Increasing the producer price of maize will thus be detrimental not only to the urban poor but also to

the rural majority who buy maize. According to Harrigon, the only hope of increasing their incomes is to encourage their use of fertilizer on "local" maize varieties, so that more of their land can be taken out of subsistence and planted to cash crops (hybrid maize, tobacco, cotton). Is this being done? No; 1989/90 data show hectarage is stable in local maize varieties. Indeed, Peters and Herrera claim that African peasants are not able to "withdraw" into autarky, as posited by Hyden's "economy of affection"— in the cases of Tanzania and western Kenya, where 40% to 50% of households depend on purchased food to a significant extent, Malawi, and even some areas of Zimbabwe, a net exporter of maize (Hyden and Peters, p. 312).

Even advocates of SAPs now agree that structural adjustment programs "have ignored or given insufficient attention to the social costs of adjustment," especially on the poor (O'Brien, pp. 35–37). Yet, they claim social impacts were at first ignored because the time required to "restore the momentum of economic growth" was underestimated. Now the donor agencies are working to improve the volume and quality of data on social effects of adjustment which can then be used to design better adjustment programs (World Bank). Others claim it is impossible to isolate out the impact of SAPs from other macrolevel phenomena, especially given the wide variety of SAPs implemented by the different African countries. We agree with O'Brien (p. 39) that "the verdict is still out" on SAPs, and more careful longitudinal impact studies, such as Ensminger's study of the Orma, need to be done. Yet, the cross-sectional studies that have been done are also useful and allow us to identify those components of SAP packages that negatively impact on FHHs and should either be dropped completely from the package or mitigated by the design of another intervention or targeted subsidy.

A fertilizer subsidy removal program currently pushed by USAID in several African countries is a component of a SAP package which should be dropped. It negatively impacts on African women farmers just now starting to use chemical fertilizers on subsistence food crops that are fertilizer-responsive, such as maize. Gladwin's results, based on a model of farmers' decisions between chemical and organic fertilizer in Malawi and Cameroon, show that women farmers want to use chemical fertilizer on maize but are constrained from its use by lack of cash and credit in both countries rather than by their beliefs in organic substitutes (manure/compost or a fallow cycle with leguminous trees). In the view of women farmers, animal manures or leguminous trees are not substitutes for chemical fertilizer; they are complements, expensive ones, and very inconvenient because maize fields are planted too far away from homes or roads. Fallow cycles (e.g., in Northwest Cameroon) are too short to be viable substitutes for chemical fertilizer in maize production. Why cannot credit be expanded to allow FHHs to invest in fertilizer? Gladwin's credit decision model shows one of the main factors limiting women farmers' use of credit is their aversion to the risks of not being able to repay loans in bad years. Poor women farmers do not want credit if they do not have a cash crop to sell in order to repay the loan, and they have learned not to sell subsistence crops needed by their families in the hunger period. From the perspective of the women, government's expanding credit is not a substitute for government's making fertilizer cheap enough, via a fertilizer subsidy, for poor women to get with cash provided by their own cash crops or husbands' savings.

What, then, do FHHs do when fertilizer subsidies are removed and both fertilizer and food prices are allowed to increase, as they have in Malawi where the price of maize doubled and the price of fertilizer increased 66% since 1986/87? Aggregate data from Malawi in table 4 show that, although the profitability of local (subsistence) maize has steadily increased, this increased profitability has not elicited an improved supply response of local maize, a nontradable. Yet, the increased profitability of hybrid maize, the men's cash crop, has elicited a more than doubling of the supply. Where has this increased hectarage of hybrid maize come from? Groundnuts, the women's cash crop, has decreased drastically in hectarage. Men are thus responding to the increased profitability of their cash crop by drawing land resources away from the women's cash crop, leaving women less able to buy fertilizer for local maize and farm it more intensively. Yet, more intensive farming of subsistence maize is the most effective way to increase cash crop production in Malawi (Harrigon).

Meena's study of the Mwanza region, Tanzania, shows similar results. An increase in crop prices has not matched the increasing price of farm implements and inputs which have been rising because of devaluation and inflation. She also observed that crops normally controlled by women, such as vegetables, fruits, peas, and beans (food crops) do not get the necessary cash

Table 4. Malawi Maize Production Data

	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
Price of maize (t/kg)	6.6	11.1	11.1	12.2	12.2	12.2	12.2	16.7	24.0	
Profitability local maize		82	80	88	87	84	82	128	187	201
Profitability hybrid maize		193	211	193	173	147	136	253	414	414
Local maize hectares (1,000 ha)				1,068	1,048	1,104	1,132	1,138	1,163	1,180
Hybrid maize hectares (1,000 ha)				89	75	69	37	59	86	135
Groundnuts prices	33.0	37.0	55.0	60.0	70.0	75.0	75.0	75.0	82.0	
Groundnuts hectares			146	145	136	176	210	176	140	48

Source: Malawi Ministry of Agriculture.

inputs. Why? Because if women do not receive cash from the sales of cash crops, they do not have money to purchase agrochemicals, both fertilizers and insecticides, for use on food crops.

In fact, increased producer prices for cash (export) crops may negatively affect women by forcing them to spend more of their time on men's cash crops, e.g., cotton, and less of their time on their own crops, vegetables and fruits. In Mwanza region, Meena claims there has been a tendency to emphasize cotton and de-emphasize the production of vegetables and fruits, for which women farmers get very low prices. In addition, men and women have previously been jointly responsible for harvesting crops. Now, however, men have been pulling out from ferrying harvested crops to market because of the increased price of bicycles, ox carts, and wheelbarrows to ferry cotton from the farms. They are no longer affordable, especially to FHHs who do not control cash income from cash crops. When men do have a means of transport, they cooperate in this activity; otherwise it becomes women's business, adding to their labor burden. Meena (p. 175) thus concludes that

> Price is thus an ineffective instrument to motivate agricultural producers in increasing production, if (1) there is a mismatch between increases in prices of necessary farm inputs and increases in producer prices, or if (2) there is no mechanism to ensure that the surplus which is accrued from the increased producer price benefits all the producers, including women. A price increase of cash crops whose income is not controlled by women cannot motivate women farmers who have nothing to gain from these increases.

Goheen's case study of land and gender in Nso, Northwest Cameroon, shows a similar institutional barrier which is exacerbated by the SAP crisis. Traditionally, land in Nso is owned by men; men and women labor on coffee, the export crop, while women, who grow virtually all the food consumed locally, have to beg for land for their crops. A decline in national food self-sufficiency over the past decade has intensified the government's interest in developing commercial agriculture in the region, so it has offered a "Young Farmers' Resettlement Program" with big tracts of previously unsettled land. But custom—and capital—dictates that only "big men" get the land, and women walk further and further away from the village to plant subsistence maize. This weakening of women's entitlements to land comes at a time when urban remittances have decreased, male relatives have not been paid for their coffee crop, and fertilizer

subsidies are being removed; it "threatens the nutritional level not only of the rural household but also of a large proportion of the national population" (Goheen, p. 241).

Conclusion

Major solutions for the agricultural sector under structural adjustment policies include higher domestic and export farm product prices, devaluation of overvalued exchange rates, lower taxes on export crops, more efficient and competitive marketing arrangements, removal of subsidies, and a switch in resources from nontradables to tradables. The higher farm product prices have encouraged greater agricultural production. These higher prices, however, will not assist and may even hurt FHHs, 25% of smallholder farm households, because little of their production is sold; these households often must reenter the market to purchase food when their own supply is exhausted. Similarly, since FHHs sell only a small percentage of their crops, more efficient and competitive marketing arrangements are not of much assistance except to the extent that this efficiency decreases the cost of their food purchases. Unfortunately, devaluation and the resulting inflation has involved higher food prices and, thus, higher food costs. To the extent that SAPs are successful in switching resources from nontradables to tradables, women, married as well as FHHs, lose out because they tend to produce mostly nontradables by sexual division of labor rules. If they have to limit their production more and more to nontradables, such as local maize in Malawi, and they lose land from their cash crop to the men's cash crop, then they also lose the cash they need to buy fertilizer to grow the nontradable crop more intensively. This eliminates their only strategy to increase income.

In addition, the consumption-oriented policies, those affecting expenditures for education and health (including family planning) especially, have been cut in real terms by the SAPs. When total government expenditures must be reduced, it is difficult for governments to maintain funding in these crucial areas which affect women's reproductive as well as productive roles.

Advocates of structural adjustment programs claim that SAPs are gender neutral and both FHHs and JHHs should benefit from improved agricultural prices and improved, liberalized marketing arrangements. Unfortunately, this is not the case. Negative impacts on women farmers and FHHs can be anticipated: (*a*) when subsidies of essential inputs (e.g., fertilizer) are removed and input prices increase more than food product prices; (*b*) when women do not have a cash crop but need purchased inputs for subsistence crops and their prices rise; (*c*) when food prices rise but FHHs are net buyers, not net sellers, of food; (*d*) when the price of export crops increase and women's labor is pulled from their own food crops to export crop production or male-controlled domestic crop production; (*e*) when women depend on remittances from male relatives for essential inputs of production, and urban wages or the price of export crops fall; (*f*) when household expenditures on health and education are increased. Note that these scenarios are common, given structural adjustment in Africa.

What should be done? Some components of SAP reform packages in some countries should be dropped completely and written off as "non-answers," e.g., fertilizer subsidy removal programs in Malawi and Cameroon. (Note that all SAP packages should be designed on a country-specific basis; a fertilizer subsidy removal program may make sense in Nigeria but not in Malawi.) Other components of SAP packages, e.g., increased food product prices, may negatively impact on FHHs but be justified by their beneficial impact on other smallholders. In this case, the negative impact on FHHs might be mitigated by a consumer subsidy or nutritional supplement program targeted at FHHs. We conclude that SAP programs are not gender neutral in operation or effect, and complementary policies—credit, fertilizer subsidies, income-generation programs, and nutritional supplementation programs for women farmers and FHHs, coupled with programs of debt forgiveness and reduced defense expenditures for their governments—are needed to mitigate the adverse effects of SAPs on women farmers.

References

Boserup, Ester. *Woman's Role in Economic Development.* New York: St. Martin's Press, 1970.

Chipande, G. H. R., M. M. Mowezalamba, L. S. Mwaisanoc, and M. W. Mhango. "*Income Generating Activities for Rural Women in Malawi: A Final Report.*" Centre for Social Research, Zomba, University of Malawi, 1986.

Dixon, Ruth. "Women in Agriculture: Counting the Labor Force in Developing Countries." *Population and Develop. Rev.* 8(1982):558–59.

Due, Jean M., and Flavianus Magayane. "Changes in Agricultural Policy Needed for Female-Headed Farm Families in Tropical Africa." *Agr. Econ.* 4(1990):239–53.

Due, Jean M., Enock Sikaponde, and Flavianus Magayane. "Does the T & V Extension System Assist Female-Headed Families? Some Recent Evidence from Zambia." *East. African Econ. Rev.* 7(1991):36–52.

Due, Jean M., and Marcia White. "Contrasts Between Joint and Female-Headed Farm Households in Zambia." *East. Africa Econ. Rev.* 2(1986):94–98.

Elson, Diane. "Male Bias in Macro-economics: The Case of Structural Adjustment." *Male Bias in the Development Process*, ed. D. Elson, pp. 164–90. Manchester UK: Manchester University Press, 1991.

——. "The Impact of Structural Adjustment on Women: Concepts and Issues." *The IMF, the World Bank, and the African Debt*, vol. 2, ed. Bade Onimode, pp. 56–74. London: Zed Books, 1989.

Ensminger, Jean. "Structural Transformation and Its Consequences for Orma Women Pastoralists." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 281–300. Gainesville: University of Florida Press, 1991.

Fortmann, Louise. "The Plight of the Invisible Farmer." *Women and Technological Change in Developing Countries*, ed. R. Dauber and M. Cain, pp. 205–14. Boulder: Westview Press, 1981.

Gladwin, Christina. "Fertilizer Subsidy Removal Programs and Their Potential Impacts on Women Farmers in Malawi and Cameroon." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 191–216. Gainesville: University of Florida Press, 1991.

Gladwin, Christina, and Della McMillan. "Is a Turnaround in Africa Possible without Helping African Women to Farm?" *Econ. Develop. and Cultur. Change* 37 (1989):345–69.

Goheen, Miriam. "The Ideology and Political Economy of Gender: Women and Land in Nso, Cameroon." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 239–56. Gainesville: University of Florida Press, 1991.

Guyer, Jane, with Olukemi Idowu. "Women's Agricultural Work in a Multimodal Rural Economy: Ibarapa District, Oyo State, Nigeria." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 257–80. Gainesville: University of Florida Press, 1991.

Harrigon, Jane. "Price Policy in Malawi." Report of Ministry of Agriculture, Lilongwe, Malawi, 1987.

Hyden, Goran. *No Shortcuts to Progress*. Berkeley: University of California Press, 1983.

Hyden, Goran, and Pauline Peters. "Debate on the Economy of Affection: Is it a Useful Tool for Gender Analysis?" *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 301–36. Gainesville: University of Florida Press, 1991.

Lele, Uma. "Structural Adjustment, Agricultural Development, and the Poor: Some Lessons from the Malawian Experience." *World Develop.* 18(1990):1207–19.

——. "Women, Structural Adjustment and Transformation: Some Lessons and Questions from the African Experience." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 46–80. Gainesville: University of Florida Press, 1991.

Meena, Ruth. "The Impact of Structural Adjustment Programs on Rural Women in Tanzania." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 169–90. Gainesville: University of Florida Press, 1991.

Mollel, Naftali M. "An Evaluation of the Training and Visit (T&V) System of Agricultural Extension in Muheza District, Tanga Region, Tanzania." M.S. thesis, University of Illinois, 1986.

O'Brien, Stephen. "Structural Adjustment and Structural Transformation in sub-Saharan Africa." *Structural Adjustment and African Women Farmers*, ed. C. Gladwin, pp. 25–45. Gainesville: University of Florida Press, 1991.

Peters, Pauline, and M. G. Herrera. "Cash Cropping, Food Security, and Nutrition: The Effects of Agricultural Commercialization Among Smallholders in Malawi." Harvard Institute of International Development, 1989.

Phiri, C. "*Women and Their Economic Activities: A Comparative Analysis of Male-Headed and Female-Headed Households in Thekerani Rural Growth Centre.*" Dep. Rural Develop., Bunda College, Zomba, Malawi, 1986.

Sikaponde, Enock. "An Evaluation of the Training and Visit (T&V) System of Agricultural Extension in Eastern Province, Zambia. M.S. thesis, University of Illinois, 1988.

Staudt, Kathleen. "Women Farmers and Inequities in Agricultural Services." *Rural Africana* 29(1975):81–93.

World Bank. *Structural Adjustment and Poverty: A Conceptual, Empirical, and Policy Framework.* Washington DC: World Bank, 1990.

Can Structural Adjustment Work for Women Farmers

Rekha Mehra

Economists have devoted considerable attention to studying the impacts of structural adjustment programs (SAPs) on agriculture. However, they have paid much less attention to the potential differential effects of such programs on women farmers who play a large and significant role in agriculture in the developing countries. Donor agencies have generally assumed that economic policies, especially price policies, which are the basis of SAPs, are gender neutral in their impacts. This assumption is increasingly being questioned as the evidence mounts that policies can have very different impacts on women farmers.

Structural Adjustment Programs and Agriculture

SAPs are economic reform programs adopted by many developing countries as the condition for obtaining loans from the International Monetary Fund (IMF) and the World Bank. During the 1980s, many countries sought such loans because they were faced with severe economic and fiscal crises caused by a combination of factors that included external shocks, especially higher oil prices, and financial mismanagement. The need for funds from the multilateral agencies has continued into the 1990s, as have SAPs, because many developing countries have been unable to pay off their debts and overcome their economic difficulties.

Most countries introduce SAPs in two phases, each associated with a distinct set of measures. In the first, or stabilization, phase the IMF makes loans to help countries overcome short-term imbalances in their current accounts if they agree to adopt demand restricting measures, such as monetary restraint and cuts in public expenditures, and demand switching measures, such as currency devaluation. In the second or adjustment phase, the World Bank offers longer-term loans to countries consenting to deregulate their economies and make them more market oriented. The objective is to improve economic efficiency and promote more rapid economic growth. A primary instrument of reform is terms of trade adjustment, the purpose of which is to remedy past inefficiencies by redirecting productive resources from nontradables to tradables, from imports to exports, and from manufacturing to agriculture. Other reforms include subsidy removal, privatization, and lowering of trade barriers.

Agriculture is an important sector affected by SAPs because of its importance to the economies of developing countries in terms of employment, income generation, and export earnings. In low-income countries with per capita incomes of $380 or less, for example, agriculture accounts for about a third of gross domestic product, 70% of employment, and a third of all exports (Johnson). In developing countries, agriculture is commonly taxed either directly, through such means as tariffs on agricultural exports or state trading, or indirectly, through currency overvaluation.

Many of the important macroeconomic reforms included in the SAP reform package have significant impacts on agriculture. Currency devaluation, for example, improves incentives to agriculture by lowering the relative prices of developing country farm commodities and making them more competitive on the international market. The reform packages also include sector-specific reforms such as reducing or removing food and input subsidies, substituting market for official output prices, privatizing government crop marketing boards, and liberalizing trade policy.

Rekha Mehra is an agricultural economist at the International Center for Research on Women, Washington D.C.

The author gratefully acknowledges the financial support of the Office of Women and Development, Agency for International Development (AID) under Contract No. PDC-0300-Z-00-8202-00 in preparing the report on which these comments are based. The views and interpretations expressed are those of the author and should not be attributed to AID.

For their comments and contributions to this paper, the author would like to thank David Bruns, Rip Landes, Margaret Lycette, and Lisa McGowan. She would also like to acknowledge the assistance of Miriam Escobar. The author is, of course, entirely responsible for the paper's content.

The Effectiveness of SAPs

Economic reform programs have been under way in some countries for more than ten years. Economists generally agree that the initial stabilization phase has been quite successful in helping borrower countries overcome short-term balance-of-payments crises. The evidence on whether SAPs increase or decrease income in the medium term is, however, unclear.

The limited information available suggests that the results of economic reform on the agricultural sector have also been mixed. Agriculture expanded in some adjusting countries (Morocco and Algeria) and stagnated or declined in many others (Indonesia, Bolivia, Costa Rica, and Mexico) (World Bank 1988). Among the developing regions, agricultural growth was slowest in Africa in the early 1980s, but 1% per annum higher in adjusting than nonadjusting countries (Cleaver).

SAPs appear to have been somewhat successful in increasing the output of export crops. Though the volume of agricultural exports from Africa as a whole declined between 1981–88 (FAO 1988), in countries of sub-Saharan Africa (SSA) with strong reform programs, the volume of exports grew. On average, export volumes increased 4.2% per annum 1985–87 compared with a rate of 0.2% for countries with weak or no reform programs (World Bank 1989). Part of the increase may have been the result of policy reforms that raised prices of major export crops by 16% from 1983 to 1986 (World Bank 1989).

Food production, however, grew slowly or not at all in many adjusting countries. In thirty-six of sixty-two adjusting countries evaluated by an FAO (1989) study, per capita staple food production grew less than 1% per annum, or was negative 1980–86. For fourteen of the thirty-six countries, poor performance represented a reversal of relatively good performance during the previous decade. Performance was weakest in Africa and Latin America. The FAO study showed that staple food production grew very little or declined for sixteen of twenty-eight African countries studied.

For the three years between 1984 and 1986, food self-sufficiency in SSA remained constant at 97% in both adjusting and nonadjusting countries (Binswanger). However, per capita food production declined in many of the adjusting countries of SSA (Lone). An FAO (1989) study of twenty-six African countries found that food consumption in both adjusting and nonadjusting countries fell 0.2% per annum. Not surprisingly, nutrition levels in sub-Saharan Africa stagnated below the internationally established daily requirement through the first half of the 1980s (World Bank 1988).

Among the reasons economists have suggested to explain why SAPs have fallen short of expectations are governmental failure to implement reforms properly and overly optimistic expectations among policy makers as to how long programs would take to show results (Haykin; Ross et al.; Wilcock, Roth, and Haykin). In agriculture, the explanation offered is that SAPs rely too heavily on price policy reform that, by itself, is insufficient to induce agricultural growth (Chibber, Commander, Lipton, Cleaver). An alternative explanation that has received little attention is that the slow response in agriculture may result from the constraints facing women, who comprise a significant proportion of farmers, particularly in sub-Saharan Africa.

The Structural Constraints Facing Women Farmers

The primary instruments used in agricultural sector reform are the realignment of prices, mainly through changes in the exchange rate that increase the price of tradables versus nontradables, and the removal of food subsidies, which raises the price of food. These measures are intended to alter prodution incentives, encouraging producers to shift resources into, and increase the production of, tradable goods whose prices increase after policy reform. The extent to which producers actually do shift resources is the economy's supply response.

The question is whether price changes alone can bring about the desired supply response given that underdevleopment is a result, at least in part, of the inadequacy of production support systems and the accompanying lack of flexibility of productive capacity. Without such flexibility, price incentives alone may be less effective than anticipated, ineffective, or actually counterproductive (Streeten). Bottlenecks in infrastructure, for example, can mean that even if farmers produce more in response to higher prices, crops cannot be transported to market, and the price incentives fail. Lag effects of reforms, whose duration depends on production support systems, can also mute the effects of price incentives. Imported inputs such as fuel and fertilizers, for example, will rise in price with devaluation and, unless efficient credit institutions are in place, smaller, resource-poor farm-

ers may be unable to survive the crop gestation period and profit by increased prices.

Limited Access to Resources

Women, who are disproportionately represented among small and resource-poor farmers, may find it especially difficult to respond to market incentives and other policy reforms. A study in Kenya, for example, found that female-headed households are only half as likely as male-headed households to grow tea (the leading export crop), even though women generally do most of the work on that crop. The likely explanation is that women farmers are unable to respond to market incentives in the expected manner because the constraints they face are more severe than those facing men (Collier).

Throughout the developing world, women farmers lack access to resources such as land, cash, and farm tools and implements. Their access to services such as credit, agricultural extension, technology, information, and basic education that are critical for shifting patterns of agricultural production or increasing output, is also limited. The ways in which each of these constraints affects women farmers and prevents them from profiting from the reforms associated with SAPs is described below.

Credit. Access to credit is critically necessary for women and small farmers to enable them to buy productive inputs and assets that could enhance their productivity and returns. In particular, they need credit to make the larger and longer-term investments required by most high-return cash crops for which SAPs provide incentives. It is well known, however, that small farmer access to institutional credit is quite limited in developing countries. It is even more limited for women farmers.

A study of thirty-eight branches of major banks in India found, for example, that only 11% of borrowers at these banks were women (Sundar). In one branch, the proportion of loans given to women was higher than the average for all branches because it was the women's branch of a nationalized bank; but, even here, for every three loans that went to women, five went to men.

In the Kakamega district of Western Province, Kenya, where approximately 40% of farms are managed by women whose husbands are working elsewhere or are absent entirely, a study revealed that of eighty-four female-managed farm households interviewed about their knowledge of loan availability, 99% knew nothing about the extension service's credit program. Only one female manager knew the application procedure (significantly, she was wealthy and linked to the local power structure), and no female manager had actually obtained a loan (Staudt).

Under SAPs, credit availability is affected mainly by credit ceilings and slower growth in the money supply to discourage public sector borrowing and spending, and by higher interest rates intended to increase the supply of credit to the private sector, including agriculture. The available evidence suggests, however, that lowering the supply of funds swamps the interest rate effect and reduces the supply of loanable funds available for agriculture. This has occurred, for example, in Brazil, where rural credit availability fell 60% between 1980 and 1984 (Castro de Rezende). Farm credit also fell in Bangladesh, and not surprisingly, women farmers were the first to be crowded out (Mahmud and Mahmud).

More important for women is what happens to nonformal credit, which is the main source of loans for women. The limited evidence that is available suggests that nonformal credit also becomes tighter under adjustment. The contributing factors are the shortage of loanable funds in the formal sector, which constrains onlending by nonformal intermediaries, and reduced household incomes, which prevent individuals from lending informally to friends and relatives. In Nigeria, Elabor-Idemudia found that friends and relatives, who had been a major source of loans for women, became increasingly reluctant to offer loans as household financial stress increased under recession and adjustment.

Agricultural extension and information. Farmers' ability to respond to incentives under SAPs depends to a large extent on their access to efficiency-enhancing techniques and technology about familiar crops and information on how to grow new and unfamiliar but more profitable cash crops. In many countries, government agricultural extension services are the main source of new information and technology, but the limited data available show that few women benefit directly from these services. This poses a significant constraint to women farmers' responsiveness to the production incentives provided under SAPs.

Studies in Africa, for example, show that male heads of households and richer farmers are the primary clients of agricultural extension ser-

vices (Bay, Bettles, Bond, Cowle). A survey in Nigeria's Ogun State Agricultural Development Project revealed that extension agents visited just 10% of women farmers every week, whereas 70% of the men received weekly visits (Elabor-Idemudia).

Aside from outright discrimination, a number of factors account for women's low participation in extension programs. To begin with, the information extension services provide is often very general or focused on particular cash crops that are being promoted at the time and does not include data on food crops, which would be of most interest to women. The methods used to disseminate technical information, such as the contact farmer approach and the use of training centers, tend to channel information to wealthier and better-endowed farmers, who are generally men (Berger, DeLancey, and Mellencamp). Finally, women's ability to participate in extension programs is limited because of their lack of education, lack of control over land, time constraints because of their dual household and economic activities, and the structure of extension programs, which tend to use mostly male agents or which schedule training sessions at times when women cannot attend.

Women's access to agricultural extension may well have declined with the introduction of SAPs, as the strictures placed on overall government spending have reduced total agricultural sector spending and imposed cuts on extension services, including staff layoffs and reductions in transport and equipment. Prior to adjustment, in twenty-seven out of thirty-four countries examined, an FAO (1989) study found government expenditures on agriculture represented less than half the sector's contribution to national income. After adjustment, the ratio was even lower. In countries such as Zambia and Ghana, governments have attempted to channel expenditures toward agriculture, but whether this reorientation can compensate for the decline in overall levels of expenditures is not clear. In the Côte d'Ivoire, for example, the increase in agriculture's share in government spending could not compensate for the dramatic drop in total spending 1983–85 (Demery and Addison). Experience suggests that women's access to extension services and training are unlikely to improve when overall funding and availability of services is declining.

Land. Lack of land ownership is yet another constraint impeding the supply responsiveness of women farmers. Lack of title to land negatively affects women's access to resources such as agricultural credit, extension services, and inputs, and their attitudes toward risk-taking, factors that can put a brake on farmer productivity and willingness and capability to adopt new crops.

Land ownership patterns vary greatly throughout the developing world, but virtually everywhere women's rights to land are restricted. In Kenya, for example, where women provide more labor than men for smallholder food and cash crop production, less than 5% of women own land (Horenstein). In Somalia, women make up 86% of subsistence farmers, but only 20% to 38% own land (McFerson). Even in places where the law allows women to own land, they seldom do. In places where women and men both have customary (and sometimes separate) rights to land, as in parts of Africa, control is still vested in men. Women depend on their husbands, other male relatives, or male community leaders for land allocations. Further, when women do have the legal right to own or use land, their holdings may be smaller, more distant, or of lower quality than those of men (Laird).

Under increasing population pressures, land shortages, and land titling, even the limited rights women currently have are being eroded. Land-titling schemes, in particular, have ignored women's customary rights and claims to land while legalizing and strengthening those of men (Lele). In Cameroon, for example, women had secure usufruct rights to land under traditional laws. Following recent privatization measures, women have no right to own land (Goheen).

Despite potential benefits for women and small farmers, especially in increasing security and improving access to credit and other resources, land reform has not featured prominently in SAPs (Addison et al.). This may result from the considerable political difficulties involved in land reform because it challenges the vested interests of powerful political groups, who often oppose it.

Education. Lack of literacy and education among women pose significant contraints upon farm production. Studies show that improvements in agriculture are strongly linked to education and that educated farmers tend to be more likely to adopt modern agricultural practices. Binswanger, for example, cites evidence that literacy raises the demand for fertilizers, increases the investment in draft power, and results in output growth.

Although the developing world has made con-

siderable progress in improving women's literacy and education in recent years, significant deficiencies persist. In 1985, just half of adult women in developing countries were literate. In Africa, only 36% of women were literate. Significant gaps remain between girls' and boys' education even at the primary level where the largest gains have been made (table 1). In 1990, just 20% of girls of the appropriate age were enrolled in primary school in Niger, for example, as compared with 38% of boys. In Senegal, primary enrollment among girls was 49% as compared with 71% for boys (World Bank 1990). Moreover, progress in literacy and education has been slowest, and the differential between female and male literacy and education is greatest, in the rural areas of developing countries (Sivard).

There is some evidence that demand reduction measures associated with SAPs may have slowed progress in womens' education. During the 1980s, public expenditures on education either declined or remained stagnant in many countries. Real per capita expenditures on education fell in about two-thirds of the countries of SSA (Commonwealth Secretariat). Between 1981–85, the Commonwealth Secretariat reports that school enrollments declined in thirty adjusting countries.

Declining public expenditure on education and higher educational costs from fee increases are likely to affect girls' education more adversely than that of boys. Although researchers have shown that fees help improve educational quality, higher fees tend to be a disincentive for poor families to send children to school. As the demand for girls' labor tends to be higher than that of boys because girls are used for both economic and household work, when higher costs compel families to choose between sending girls or boys to school, they tend to send the boys and keep girls at home. Girls' enrollment and school attendance may also decline in economically stressful times because their workloads tend to increase as women undertake more paid and unpaid work to supplement household financial resources and compensate for cutbacks in public sector services such as health care, sanitation, and so on.

Table 1. Female Education as a Percentage of Male Education, 1980

	Numbers Enrolled	
	First and Second Level	Third Level
Latin America	96	77
Middle East	69	41
South Asia	56	34
Far East	84	57
Oceania	76	25
Africa	75	36

Source: Sivard.

Time Constraints

Time limitations resulting from women's economic and home production roles also significantly affect their ability to respond to agricultural reform incentives, particularly those that require additional labor inputs. In contrast to men, women are primarily responsible for household production chores, such as childcare and cooking, in addition to their farm production and marketing activities.

Women's dual work obligations involve significant amounts of time and can be so burdensome that they continuously keep women at the limits of their physiological capabilities. In parts of East Africa, women work sixteen hours a day doing housework, caring for children, preparing food, and raising between 60% and 80% of the food for the family (Fagley). Nigerian women work from fifteen to nineteen hours per day, eight to ten of which are spent on farming activities. In contrast, men spend only six to eight hours per day in farming during the busiest times and about one-half hour per day on household chores (Elabor-Idemudia).

There is growing evidence that SAPs put additional demands on women's time. Policy reforms that induce farmers to expand production or adopt new crops requiring additional labor inputs, raise the demand for household labor. Although only limited information is available from the structural adjustment experience, project evidence shows that when the demand for household labor rises, women's time constraints become intensified—not those of men. In parts of Africa, where women and men grow separate crops and share the labor on others, women and men are by custom mutually obligated to exchange labor. But the terms of trade for this exchange are inherently unequal and unfavorable to women (Palmer). The obligations owed by women are more strictly enforced, and when labor demands conflict, men's demand for women's labor takes precedence.

Often, women can meet the new demands only by reducing their own production, thereby low-

ering personal earnings and sacrificing their autonomy. Although both women and men in Ghana grow cocoa, under the pressure of declining cocoa returns in the 1960s, there was an increase in men's demand for the unpaid labor of women from their own households to substitute for hired workers (Mikell). The new demands left women unable to devote adequate time to their own production. As a result, productivity on women's farms declined. By 1972, women's cocoa production and income had fallen drastically, while men's production had reached a new high. Women were thus forced out of "own-account" cocoa farming, while dependency on their husbands increased correspondingly.

Demand-reducing measures that limit public services, increase consumer costs, and lower real incomes have also caused women in many adjusting countries to assume a larger proportion of the burden of meeting their families' basic survival needs by increasing their paid and unpaid workloads. These additional responsibilities further constrain women's time availability. Women traders in Ghana, for example, reported an increase in their unpaid household work as a result of public service cutbacks due to SAPs (Clark and Manuh). The Commonwealth Secretariat reported that reductions in health care availability in many adjusting countries forced women, the primary caregivers in households, to assume the increased burden of caring for sick family members at home. Under increasing time pressure, the issue of women undertaking new and expanded farm activities in response to price reform incentives becomes purely academic.

The Need to Ensure Food Security

The priority given to ensuring household food security may be yet another factor that limits women's supply responsiveness because it keeps a proportion of resources "locked" into food and prevents them from being shifted into nonfoods. Evidence available from crop diversification projects in many developing countries, including the Gambia, Guatemala, Kenya, the Philippines, and Rwanda shows that smallholders make a conscious effort to maintain household food production alongside newly introduced cash crops (von Braun). There is some evidence that in times of economic crisis especially, small farmers react by intensifying household food production. In Uganda, for example, throughout the economic mismanagement and political turmoil of the 1970s, the food situation remained basically healthy mainly because farmers, and in some cases urban residents, continued to grow their own food (Jamal).

The tendency to ensure household food security seems to be characteristic of small farmers in general, but it may be more of a constraint for women because they generally have greater responsibility for supplying household food needs, especially in Africa. Even where women are not explicitly responsible for providing food, poor women often assume this role, especially when households come under economic stress. Under adjustment, food insecurity among the rural poor may increase because food prices are higher as a result of subsidy removal or currency devaluation that increases the price of imported foods. Declining levels of employment, real wages, and incomes may also contribute to growing food insecurity. The rise in food prices would affect the rural poor because many poor farm households are net purchasers of food. According to one study, net buyers of staple cereals comprise 66% of rural households in Rwanda, 61% in Somalia, and 39% in Mali (Sahn).

Conclusions and Policy Implications

By disregarding the numerous structural constraints facing women farmers, who account for a large share of farm producton in developing countries, policy makers may have inadvertently restricted the effectiveness of structural adjustment programs. The solution would be to attempt to alleviate these constraints by implementing complementary policies that reallocate available productive resources and new technologies to women. As women's labor is currently an underutilized resource, such policies could yield higher marginal returns and greater output without additional investments, thereby mitigating some of the short-run output dampening effects experienced by most adjusting countries. They would also be more equitable.

In the long run, however, it would still be necessary to address the constraints preventing all small farmers in developing countries, men and women alike, from being fully responsive to price policy reforms. This will require improvements in production support systems, such as roads and transport, and agricultural support services, such as extension and credit, that in turn require not only greater efficiency but also larger investments. Finally, the needed invest-

ments can occur only under current conditions of persistent recession and huge debt burdens in developing countries if countries cooperate to resolve such issues as the debt crisis and the outflow of capital from developing countries.

References

Addison, Tony, Lionel Demery, Jeffrey Round, Tom Stephens, and Marco Ferroni. *Structural Adjustment and Poverty: A Conceptual, Empirical and Policy Framework.* Washington DC: World Bank, 1989.

Bay, Edna, ed. *Women and Work in Africa.* Boulder CO: Westview Press, 1982.

Berger, Marguerite, Virginia Delancey, and Amy Mellencamp. *Bridging the Gender Gap in Agricultural Extension.* Report prepared for the Office of Women in Development/USAID. Washington DC: International Center for Research on Women, 1984.

Bettles, F. M. "Women's Access to Agricultural Extension Services in Botswana." Paper prepared for Ford Foundation Workshop on Women in Agricultural Production in Eastern and Southern Africa, Nairobi, 9–11 April 1980.

Binswanger, Hans. "How Agricultural Producers Respond to Prices and Government Investments." Paper presented at First Annual World Bank Conference on Development Economics, Washington DC, 27–28 April 1989.

Bond, C. A. *Women's Involvement in Agriculture in Botswana.* Gaborone, Botswana: Ministry of Agriculture, processed 1974.

Castro de Rezende, Gervasio. "Brazil 1981–6." *Structural Adjustment and Agriculture: Theory and Practice in Africa and Latin America,* ed. Simon Commander, pp. 202–17. London: Overseas Development Institute, 1989.

Chibber, Ajay. "The Aggregate Supply Response." *Structural Adjustment and Agriculture: Theory and Practice in Africa and Latin America,* ed. Simon Commander, pp. 55–70. London: Overseas Development Institute, 1989.

Clark, Gracia, and Takyiwaa Manuh. "Women Traders in Ghana and the Structural Adjustment Programme." *Structural Adjustment and African Women Farmers,* ed. Christina H. Gladwin, pp. 217–36. Gainesville: University of Florida Press, 1991.

Cleaver, Kevin. *Agricultural Policy Reform and Structural Adjustment in Sub-Sahara Africa: Results to Date.* Washington DC: World Bank, processed 1988.

Collier, Paul. *Women and Structural Adjustment.* Washington, DC: World Bank, draft 1989.

Commander, Simon. "Prices, Markets and Rigidities: African Agriculture 1980–88." *Structural Adjustment and Agriculture: Theory and Practice in Africa and Latin America,* ed. Simon Commander, pp. 228–43. London: Overseas Development Institute, 1989.

Commonwealth Secretariat. *Engendering Adjustment for the 1990s.* London, 1989.

Cowle, W. J. "Aspects of Resource Access among Villagers and Farmers in the Kenyanja Parish, Chipata District." *Poverty and Wealth in Rural Zambia,* ed. David Honeybone and Alan Marter. Institute for African Studies Communication no. 15, University of Zambia, 1979.

Demery, Lionel, and Tony Addison. "Food Insecurity and Adjustment Policies in Sub-Saharan Africa: A Review of the Evidence." *Develop. Pol. Rev.* 5(1987):177–96.

Elabor-Idemudia, Patience. "The Impact of Structural Adjustment Programs on Women and Their Households in Bendel and Ogun States, Nigeria." *Structural Adjustment and African Women Farmers,* ed. Christina H. Gladwin, pp. 128–50. Gainesville: University of Florida Press, 1991.

Fagley, R. M. "Easing the Burden of Women: A Sixteen-Hour Workday." *Assignment Children* 36(1976):9–28.

Food and Agriculture Organization of the United Nations (FAO). *Effects of Stabilization and Structural Adjustment Programmes on Food Security.* Committee on World Food Security, Fourteenth Session, Rome, 3–7 April 1987. Rome, 1989.

——. *FAO Annual Production Yearbook,* vol. 42. Rome, 1988.

Goheen, Miriam. "The Ideology and Political Economy of Gender: Women and Land in Nso, Cameroon." *Structural Adjustment and African Women Farmers,* ed. Christina H. Gladwin, pp. 239–56. Gainesville: University of Florida Press, 1991.

Haykin, Stephen M. *Policy Reform Programs in Africa: A Preliminary Assessment of Impacts.* Washington DC: USAID, Bureau for Africa, Office of Development Planning, 1987.

Horenstein, Nadine R. *Women and Food Security in Kenya.* Washington DC: World Bank; Policy, Planning, and Res. Work. Pap. No. WPS232, Population and Human Resources Department, 1989.

Jamal, Vali. *Structural Adjustment and Food Security in Uganda.* Geneva: International Labour Office, World Employment Programme Res. Work. Pap. No. 10-6/WP73, 1985.

Johnson, D. Gale. "Agricultural Structural Policies." Symposium on Growth-Oriented Adjustment Programs, Washington DC, 25–27 Feb. 1987. Washington DC: World Bank and International Monetary Fund, 1987.

Laird, Judith Fincher. *Rural Women in Paraguay: The Socio-Economic Dimension.* Report prepared for the Agency for International Development, Office of Women and Development, Washington DC, 1979.

Lele, Uma. "Women and Structural Transformation." *Econ. Develop. and Cultur. Change* 34(1986):191–221.

Lipton, Michael. "Limits of Price Policy for Agriculture: Which Way for the World Bank?" *Develop. Pol. Rev.* 5(1987):197–215.

Lone, Salim. "African Adjustment Concerns Gaining Support." *African Recovery,* no. 1–2 (1989), p. 1.

Lycette, Margaret. *Improving Women's Access to Credit in the Third World: Policy and Project Recommendations.* Washington DC: International Center for Research on Women Occas. Pap. no. 1, 1984.

Mahmud, Simeen, and Wahiduddin Mahmud. *Structural*

Adjustment and Women: The Case of Bangladesh. Dhaka: Bangladesh Institute of Development Studies, 1989.

McFerson, Hazel M. *Women in the Economy of Somalia.* Revised version of a report prepared for USAID/Somalia, Mogadishu, for the Privatization and Policy Initiatives (PIPS) Project, Socioeconomic and Policy Studies, processed 1989.

Mikell, Gwendolyn. "Ghanaian Females, Rural Economy and National Stability." *African Stud. Rev.*, no. 3(1986), pp. 67–88.

Palmer, Ingrid. *Gender Issues in Structural Adjustment of Sub-Saharan African Agriculture and Some Demographic Implications.* Geneva: International Labour Office, World Employment Programme Res. Work. Pap. 2-21/WP166, 1988.

Ross, Clark, Philip Boyle, Don Harrison, and Charles Nicholson. *The Effects of Structural Adjustment in Senegal.* Report prepared for Bureau for Africa, Office of Development Planning, U.S. Agency for International Development. Washington DC: Robert R. Nathan Associates, 1987.

Sahn, David E. "Poverty, Food Security, and Policy Reform in Africa." *Macroeconomic Policy Reforms, Poverty, and Nutrition: Analytical Methodologies,* ed. Per Pinstrup-Andersen. New York: Cornell Food and Nutrition Policy Program, 1990.

Sivard, Ruth Leger. *Women: A World Survey.* Washington DC: World Priorities, 1985.

Staudt, Kathleen A. "Women Farmers and Inequities in Agricultural Services." *Women and Work in Africa,* ed. Edna Bay. Boulder CO: Westview Press, 1982.

Streeten, Paul. "A Survey of the Issues and Options." *Structural Adjustment in Agriculture: Theory and Practice in Africa and Latin America,* ed. Simon Commander, pp. 3–18. London: Overseas Develoment Institute, 1989.

Sundar, Pushpa. "Credit and Finance Needs of Women Workers." No date.

von Braun, Joachim. *Commercialization of Smallholder Agriculture: Policy Requirements for Capturing Gains for the Malnourished Poor.* Washington DC: International Food Policy Research Institute, 1989.

Wilcock, David C., Alan D. Roth, and Stephen M. Haykin. *Cereals Marketing Liberalization in Mali: An Economic Policy Reform Assessment.* Report prepared for Bureau for Africa, Office of Development Planning, U.S. Agency for International Development. Washington DC: Robert R. Nathan Associates, 1987.

World Bank. *Adjustment Lending: An Evaluation of Ten Years of Experince.* Policy and Res. Ser. No. 1, Country Economics Department. Washington DC, 1988.

——. *Africa's Adjustment and Growth in the 1980s.* Washington DC, 1989.

——. *Social Indicators of Development 1990.* Baltimore MD: Johns Hopkins University Press, 1990.

The Gendered Impacts of Structural Adjustment Programs in Africa: Discussion

David E. Sahn and Lawrence Haddad

Why is the subject of gender and economic reform and adjustment so controversial? We believe the controversy centers on two main points.

First, there is a tendency to ignore the reinforcement effect that pre-reform distortions have on culturally based pro-male biases. The inability to collect distortion-enhanced economic rents is linked to an individual's low economic and social status and, therefore, to an individual's gender. Ignoring this point leads many to conclude, erroneously we think, that economic reform and adjustment policies are directly responsible for the low welfare levels of women as producers, consumers, and providers. However, to say that economic reforms and adjustment aim to make economic welfare reflect more accurately the resources an individual commands—rather than an individual's gender—provides little comfort to women; quite the contrary, in the post-reform environment the inequities and the foregone productivity gains are out in the open for all to see.

Second, while we have no argument with the fact that gender is a potentially valid dimension along which to examine the equity and efficiency effects of economic reform and adjustment, we would like to see the utility of this approach scrutinized more closely. When is gender the most appropriate first-order disaggregation? Under what circumstances would we better understand the fundamental, structural cause of the problem by examining distributional impacts across size of landholdings, region, tenure status, employment status, or occupational sector? When, for any one of these first-order disaggregations, is gender an important second-order disaggregation? Gender should not be the automatic starting point of an analysis of adjustment, nor should it be ignored as a potential starting point. We encourage the avoidance of approaches that are gender-blinded or gender-blind. In short, we caution against extreme views.

David Sahn is Deputy Director, Cornell University Food and Nutrition Program, Washington, D.C., and Ithaca NY; and Lawrence Haddad is a research fellow, International Food Policy Research Institute.

Linkages between Adjustment and Living Standards

Two primary pathways can be identified through which adjustment affects the poor and vulnerable. The first is through removal of distortions, including subsidies and rent seeking, in markets that affect employment, incomes, factors payments, and prices. The second is through changes in fiscal policy, particularly in regard to public expenditures.

Preadjustment Distortions, Economic Rent Collectors, and Market Reforms

The results of recent research[1] that has examined the effects of policy reform in sub-Saharan Africa on poverty provide an appropriate basis for supporting the broad propositions that (*a*) women are not served by the market distortions that reform and adjustment policies seek to remove and (*b*) the prereform economic rent collectors will seek to protect their interests, even if they impede successful adjustment and reform, and hence implementation of reforms may be less bold than is desirable. The relevant results of recent studies can be summarized in six points.

First, prior to embarking on economic reform, the conditions of women and the poor in general were abysmal. The economic distortions, lack of incentives, and market failures caused and/or aggravated by state controls in the economy impeded growth and created scarcities that had especially harsh effects on the poor

[1] This section is based on Sahn 1991.

and vulnerable, particularly women and children.

Second, the greatest impediment to the sustained improvement of the plight of women during the period of adjustment is that many reform programs have only dealt peripherally with the fundamental structural distortions extant in the economic and institutional fabric of African countries. As a consequence, some of the causes of factor and product market failure that led to the impoverishment of women have gone unaddressed. This is partially a reflection of a third point, that political empowerment of the poor and disenfranchised, of which women represent one important group, has been slow in coming.

Fourth, adjustment has focused on reforming markets for credits, inputs, land, food products, foreign exchange, and so forth. In some cases, progress has proven difficult because those who benefitted from distortions were effective in protecting their interests, rather than in any higher concerns of policy makers over the plight of the vulnerable individuals and households. Where privatization of food markets has occurred, especially in West Africa, women have been particularly well-served, given their traditional role in commerce and as traders, salespersons, and so on. In fact, evidence from throughout Africa strongly suggests that, where market liberalization has occurred, consumer prices have generally declined, while the producer prices of exportables, importables, and home goods have not suffered. This is a reflection of the increased efficiency of private sector agents, coupled with the removal of various marketing restrictions (e.g., cross-regional commodity trade restrictions or the requirement that commodities be sold to large, high-priced, and inefficient commercial mills). This has lowered transaction and transformation costs.

Fifth, and on a related matter, a review of consumer food subsidies, both explicit and implicit, in sub-Saharan Africa once again indicates that, with few exceptions, government spending on these programs has not been targeted to the poor and vulnerable. Rather, subsidized foods have been quantity constrained, with the rationed commodities almost always going to the urban population and the more powerful institutions and better-off household groups within it. Similarly, subsidies on credit and fertilizer, also prominent and the focus of reforms, have been rationed and directed toward larger, commercial farmers rather than smallholder subsistence producers where women are disproportionately represented. Thus, the removal of the subsidies will not have major deleterious consequences for those who had only very limited access to rationed fertilizer or food. These groups will, in fact, stand to benefit from reforms that remove the possibility for rent seeking on the part of the more powerful farmers and consumers.

Public Expenditure Reforms

The second major pathway through which adjustment will affect women is fiscal policy and, more specifically, through changes in the pattern and level of public expenditure.[2] A review of public expenditure policy in sub-Saharan Africa reveals that the effects of economic reforms, as mediated through the public sector, have generally not had deleterious effects on the poor and vulnerable, such as women and children. This is the result of a trio of factors. First, the infusion of foreign financing through policy-based lending from international financial institutions and bilateral donors has sustained, and in many cases increased, total expenditures in the region, both in real terms and as a share of GDP. Thus, the demand contraction often associated with the stabilization aspect of adjustment has not been a prominent feature in Africa, unlike in Latin America. Second, the elasticities of spending on health and education with respect to total expenditures were markedly higher in the "post-adjustment years" of 1985–87 than the period 1974–84. This suggests that health and education spending were increasing at a more rapid pace and receiving a larger share of the pie in recent years. Third, and most problematic, is that the intrasectoral allocation of health and education spending prior to adjustment was incredibly skewed toward secondary and tertiary services in health and education and overtly biased against poor households headed by women or where women were playing key roles as income earners and child care providers. Experience has proven it difficult to revamp health and education systems in order to address these biases. However, instituting user fees that force the rich to pay for their disproportionate use of government services will help expand the availability of services for women and the poor.

General Conclusions

The above discussion leads to several general conclusions. First, it is important not to confuse

[2]This section is based on Sahn, forthcoming.

the process of economic reform with the economic crisis and related distortions that discriminated against women and led to their low status. Second, perceived solutions to improve or protect the plight of women, such as the continuation or expansion of distortionary subsidies that promote rent seeking and thus end up primarily benefiting the rich and impeding economic growth, or maintaining bloated government bureaucracies that fail to deliver social services to vulnerable groups, need to be more critically examined. Third, removing a variety of rules and regulations, often enforced by male-dominated parastatals, will present new opportunities for women to become engaged in markets that have long been under the control of the state. Fourth, government efforts in promoting equal opportunity in education, promulgating antidiscrimination laws and rules that provide equal access to credit and market information, and facilitating participation by women in the political process, ownership of assets, and so forth, need to accompany reform efforts. These proactive policies will prove more beneficial to women rather than reactively calling for the continuation and expansion of distortions such as price controls or state intervention in markets. Regardless of original intent, these controls will likely create rent-seeking opportunities that end up discriminating against women and the poor. Fifth, there is a paucity of empirical evidence on which to judge how women are being affected by reforms. While efforts are now being made to examine the macroeconomic, sectoral, and household impacts of adjustment, both through the development of appropriate models and collection of relevant data, the problem of gaining further insight into the importance and experience of gender-specific outcomes lags behind, which in turn suggests research issues and priorities for further study.

The Relative Importance of the Gender Disaggregation

In this section we assert that until the absolute argument for gender as a disaggregation useful for policy is given some context, it is easy either to ignore the argument or to simply treat it as unassailable. While making the absolute case for gender is straightforward, making the relative case is not. There are two main reasons for this. The first is pedestrian, but important: lack of gender-disaggregated data. The second is conceptual: how to capture the gender-differentiated interactions between welfare, efficiency, and the success of adjustment in order to permit an investigation of the consequences of neglecting gender?

Recently, high-quality household-level data that is extremely rich in a broad sense (such as the World Bank Living Standards Survey) has been collected. It, like most data sets with national coverage, nonetheless lacks gender-disaggregated information in key sections, credit and farm labor, for example. Classification by gender of household head remains the only option. While data exist upon which to account for and describe the heterogeneity of these female-headed households, much information is lost about women in male-headed households. Furthermore, little is known about the dynamics of how households become female headed and what was the contribution of market distortions to this emerging problem.

Even if appropriate data existed, an integrated analytical framework that allows for the interactions between welfare, efficiency, and the success of adjustment to vary by an individual's characteristics—gender, for example—is missing. Addressing this problem, for example, suggests that where gender-disaggregated data on occupational status exist, they should be organized into broad occupational sectors that correspond to the macromodel of the economy. Multiple-occupation individuals make this task all the more difficult.

Purely on efficiency grounds, the absolute case for looking at the interaction of gender issues with adjustment issues rests on the bearing an individual's gender has on the answers to the following four questions about pre-reform conditions. What is (*a*) the need (or expectation) for, and (*b*) the ability of, the individual to bear the burdens of fiscal restraint policies or reap the benefits of equity-oriented public expenditure restructuring associated with economic adjustment packages? In addition, what is (*c*) the need and (*d*) the ability of the individual to contribute to an improvement in supply response—a key goal of structural adjustment? There is much credible evidence, from both anthropologists and economists, to suggest that prereform conditions favor men.[3] In general, and relative to men, women act as household economic "shock absorbers" but are nevertheless poorer and less able to sustain this role. The smaller

[3]For example, see the three case studies in *Gender and Adjustment*, prepared for the Office of Women in Development, USAID, by Mayatech Corporation Series TR-91-1026-02, 1991.

body of evidence on the supply-response side suggests that women are located in sectors in which resources will need to be withdrawn, but that women are less able to do so, and even if they can, they will have trouble acquiring complementary inputs.[4] Needless to say, more empirical research is needed on each of the four key questions and how the answers to them are affected by the course of adjustment policies. Moreover, any integrated model has to be able to account for not only the intra- but also the interindividual simultaneity between the needs and abilities represented in the four questions. Modeling such changes is a formidable challenge.

Nevertheless, we should remember the importance of not being gender blinded. One illustration of this is provided by Lele, who summarizes some lessons to be drawn from the Malawian experience of structural adjustment with little reference to gender issues. One of her conclusions is that it is the low income of some smallholders (and the consequent higher levels of risk aversion) which serves as one of the primary constraints to rapid supply response in Malawian agriculture. How useful is gender as a first-level disaggregation for policy analysis here? If the most important reason leading to these smallholders being among the poorest is that they are female-headed households (either *de jure* or *de facto*), then gender might be the foremost dimension to the problem. But surely, even here, our starting point should be to ask, first, what policies have contributed to a high share of poor rural smallholder households being headed by women, and, second, why these farmers are less able to contribute to the supply response. The imposition of a gender perspective on the problem a priori may well prove to be a distraction from fundamental issues of distortions in factor and product markets that have not been addressed by adjustment and that not only contribute to the impoverishment of rural smallholders but also compel men to migrate in search of employment opportunities (Sahn 1991).

In summary, then, and at the very least, we acknowledge that an improved understanding of the welfare impacts of adjustment and the probability of adjustment's success in promoting growth may well be gained through a gender-disaggregated analysis. However, the set of circumstances under which gender, in a sample-size constrained world, would be the primary disaggregation of interest remains unclear.

[4]One complaint with some of this literature is that women's poor access to resources is not compared to men's; thus, we call for more studies to cast themselves as "gender and adjustment" rather than "women and adjustment."

References

Lele, Uma. "Structural Adjustment, Agricultural Development and the Poor: Some Lessons from the Malawian Experience." *World Develop.* 18(1990):1207–19.

Sahn, David. "Has Policy Reform Hurt the Poor in Africa?" Paper prepared for the meeting of the World Bank Special Program of Assistance to Africa. Tokyo, October 1991.

——. "Public Expenditures in Sub-Saharan Africa During a Period of Economic Reforms." *World Develop.*, in press.

Sahn, David, and Jehan Arulpresasan. "The Stagnation of Smallholder Agriculture in Malawi: A Decade of Structural Adjustment." *Food Pol.* 16(1991):219–34.

The Gendered Impacts of Structural Adjustment Programs in Africa: Discussion

Uma Lele

For many African countries that have experienced prolonged macroeconomic disequilibria, adhering to structural adjustment is essential to restore macroeconomic balance. Restoration of macroeconomic balance is a necessary condition for resuming growth. However, African agriculture faces another set of "structural" problems. The question, therefore, is not whether to undertake structural adjustment but rather how to resume growth through restoration of macroeconomic balance in situations of these other structural problems. The structural problems include the skewness of land access and unequal political power, inadequate access of small farmers to agricultural extension and credit, among others.

Increasing pressure on the land caused by the rapid growth rate of population has caused a declining fallow and reduced soil fertility (Lele and Stone; Lele, Christiansen, and Kadiresan). Much of the growth in food and agricultural production has come about from area increase. With the decline in per capita food and agricultural production, growing food imports, and stagnating exports, the proportion of the households dependent on the market for food has been increasing. Furthermore, rapid urbanization and male migration has resulted in a growing incidence of female-headed households in the population.

The MADIA study carried out in the World Bank documented the range of these structural problems in Africa, lending support to many of the concerns expressed by Due and Gladwin. It concluded, for instance, that fertilizer pricing, subsidy, and distribution policies together with the alleviation of technological and institutional constraints are some of the most pressing issues in the modernization of African smallholder agriculture (Lele, Christiansen, and Kadiresan, p. 6). But the study also showed overwhelmingly that poverty-oriented programs carried out in the 1970s did not address these structural problems. They did not reach the people they intended to benefit either because they were poorly designed or were not implemented effectively, leading to closure of many of the projects.

A factor explaining the lack of growth in factor productivity is the low level of use of modern inputs. Despite massive donor assistance, Africa's per hectare use of chemical fertilizers remains the lowest in the world. Moreover, Africa's share in the fertilizer consumption of the developing world has declined.

Notwithstanding these general trends, as Due and Gladwin emphasize, considerable variation among countries calls for a location-specific understanding of the problems. The fact of the matter is that many of the problems identified by Due and Gladwin existed even before the adjustment process was initiated. Similarly, detailed country-by-country analysis carried out in the MADIA study showed that during much of the 1980s (prior to commencement of structural adjustment) nutrient price/crop price ratios for maize were substantially higher in the three East African countries than the three West African countries selected for analysis, e.g., 10.3 in Malawi in 1987/88 compared to 1.4 in Nigeria in 1987 (see table 1).

Furthermore, evaluation of the data on fertilizer trials illustrated that, despite the fact that physical response of maize to fertilizer use in Malawi was three to four times as high as in Nigeria (see table 2), without a subsidy the benefit-cost ratios were substantially below the minimum necessary in Malawi to make fertilizer use attractive to smallholders including women-headed households. The problem of these poor households did not commence with structural adjustment. It existed before, but simply got worse as a result of structural adjustment.

The large year-to-year variability in benefit-cost ratios resulting from changes in interna-

Uma Lele is a graduate research professor of international economic development, Food and Resource Economics Department, University of Florida.

Table 1. Nutrient Price/Crop Price Ratios for Maize

East Africa	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88
Malawi	8.8	7.8	9.1	9.0	9.9	12.2	12.5	10.3
Kenya	6.2	7.2	4.5	5.0	5.2	NA	3.4	4.5
Tanzania	5.6	5.4	5.1	4.1	2.2	4.2	5.0	5.0
West Africa	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**
Cameroon	2.2	2.1	2.4	NA	NA	NA	NA	NA
Senegal	1.9	1.5	1.5	2.9	3.2	2.4	2.6	2.9
					(4.2)	(4.2)	(3.6)	(3.6)
Nigeria	0.3	0.5	0.6	0.6	0.6	0.7	1.4	1.4

Note: Figures in parentheses are ratios for the unsubsidized price of fertilizier in Senegal. These ratios are computed using fertilizer prices that reflect subsidies and the effect of grant aid fertilizer on cost. The ratio does not reflect internal transport costs. MADIA Discussion Paper 5, pp. 34, 36.

Table 2. Benefit-Cost Ratios for Fertilizer Use for Maize

Kenya 1987	High Potential Land	Medium Potential Land	Low Potential Land
Government	3.4–5.9	2.3–4.8	2.0–3.2
FAO: Western & Nyanza		3.5	
Rift Valley		2.7–4.9	
Central & Eastern	3.6–5.7		

	Local				Hybrid			
Malawi 1987–88	With Subsidy	Without Subsidy	Without Explicit Subsidy	Without Explicit or Implicit Subsidy	With Subsidy	Without Subsidy	Without Explicit Subsidy	Without Explicit or Implicit Subsidy
Government (ASA)	2.0		1.6		2.6		2.9	
FAO	—		—		1.9–3.6		1.5–2.9	
World Bank	1.3		1.1		2.9		2.3	
Tanzania 1984								
FAO	—				3.4–4.0			
World Bank	1.5				3.9			
Tanzania 1987								
FAO			—	—			2.7–3.1	1.5–1.8
World Bank			1.2	0.8			3.2	2.1
Tanzania 1988								
FAO	—	—			2.9–3.4	1.0–1.2		
World Bank	1.3	0.5			3.5	1.4		
Cameroon 1987	Maize							
FAO	5.1		1.5	1.3				
IFDC	7–11		2–3	1.9–2.9				
Nigeria 1985								
FAO	6–26		3–12	1.6				
A.O. Falusi	9–20		4.9	2.5				
World Bank	7–9		3–4	1.8–2.0				
Nigeria 1987								
FAO	3–12		0.5–2.0	—				
A.O. Falusi	4.9		0.7–1.7	—				
World Bank	3–4		0.5–0.7	—				

Source: Condensed from MADIA Discussion Paper 5, pp. 44, 45, tables 23, 24.

tional and domestic prices of fertilizers and output and changes in yields of course increases the risk for the poor. The study concluded that, although increased food production as a result of increased food prices will reduce market prices of maize which women will buy, fertilizer prices in Malawi also needed to be subsidized to make its use attractive to risk-averse, near landless farmers, many of whom are women-headed households (Lele 1990). Women largely sell their labor for living and depend on the market for food. They urgently need assistance for increasing food productivity to alleviate poverty and to avert one of the greatest incidences of malnourishment among children below the age of five.

Subsidies targeted to low income households, however, have not been easy to implement in practice. In Malawi, the cheaper fertilizer is leaked to the estates that have the exclusive right to produce export crops and to receive international parity prices for their output. Small farmers cannot obtain licenses to grow high-value crops and receive one-half to a third of the parity price from the parastatal ADMARC for the crops they are allowed to grow. Even without such a dual system of production and marketing, in Nigeria much of the subsidized fertilizer in the northern ADPs has benefitted the politically powerful large farmers (Lele et al.). Small farmers have paid near-market prices for fertilizers. If the budgetary costs and abuse of the fertilizer subsidies are to be contained, ensuring that subsidies benefit those for whom they are intended becomes a major operational challenge.

In Malawi, targeting has been attempted by packaging fertilizer in small quantities which would be unattractive to large producers. Similarly, fertilizer-for-work programs have been tried in the case of near-landless households. In addition, greater monitoring of the allocation and uses of credit and fertilizers is necessary, based on the type of micro information Due and Gladwin have collated. Moreover, a level playing field is needed among farms of different sizes in terms of the farmers' access to know-how, inputs, rights to grow crops, and access to markets. Lack of equal opportunity to small farmers was a bone of contention between African governments and donors in the 1970s when integrated rural development projects were being implemented (Lele 1990, forthcoming). Enamored by large-scale farming, all too often governments have not shown the necessary commitment to reach rural poor households. Due and Gladwin are correct in arguing that in the period of structural adjustment donors have often been less than sensitive toward the plight of the poor, but the primary responsibility for reaching the poor must lie with governments.

There are two areas, however, in which I place a different emphasis than do Due and Gladwin. One relates to the dichotomy between food and export crop production which they stress. I have argued elsewhere that there is a need to provide a policy and institutional framework which fosters the production of both food and export crops without favoring either. Food crop productivity increases release land and labor for the production of nonfood crops, thereby facilitating diversification of production and increasing farm income. Increasing production of nonfood crops increases food security of households by increasing income and command over purchased food. The frequent swings in the pendulum between food and export crops has posed numerous problems in achieving sustained growth in smallholder productivity (Lele, forthcoming).

The second area of my different emphasis relates to the complementarity between the men's and women's access to factors of production and income. Several studies in Africa have stressed the benefits of increased income derived from export cropping for all members of the household including women (von Braun, Kennedy, and Bouis) when both men and women in the family work on the farm. This, of course, is not relevant for women-headed households, although by increasing employment export cropping benefits them indirectly. Increasing womens' access to inputs and services thus should not come at the cost of increasing overall access of smallholder households.

To design appropriate country- and location-specific interventions that Due and Gladwin recommend requires microlevel information of the type they have presented. That information in turn calls for the availability of indigenous personnel to develop the necessary information on a large scale if macroeconomic impact is to be achieved. Flexibility in approach is also essential to fine-tune interventions, in light of the actual implementation experience. Finally, governments and donors need to go beyond generalized solutions that extol the virtues of private enterprise or public interventions to adopting pragmatic solutions.

References

Lele, U. "Agricultural Growth, Domestic Policies, the External Environment, and Assistance to Africa: Lessons

of a Quarter Century." MADIA Disc. Pap. No. 1. Washington DC: World Bank, 1989.

——. "Structural Adjustment, Agricultural Development and the Poor: Some Lessons from the Malawian Experience." *World Develop.*, vol. 18, No. 9, pp. 1207–19. Oxford: Pergamon Press, 1990.

Lele, E., ed. *Aid to African Agriculture: Lessons from Two Decades of Donor Experience.* Washington DC: World Bank, forthcoming.

Lele, U., R. Christiansen, and K. Kadiresan. "Fertilizer Policy in Africa: Lessons from Development Programs and Adjustment Lending, 1970–87." MADIA Disc. Pap. No. 5. Washington DC: World Bank, 1989.

Lele, U., A. T. Oyejide, V. Bindlish, and B. Bumb. *Nigeria's Economic Development, Agriculture's Role, and World Bank Assistance: Lessons for the Future.* Washington DC: World Bank, year unknown.

Lele, U., and S. W. Stone. "Population Pressure, the Environment, and Agricultural Intensification: Variations on the Boserup Hypothesis." MADIA Disc. Pap. No. 4. Washington DC: World Bank, 1989.

von Braun, J., E. Kennedy, and H. Bouis. "Comparative Analyses of the Effects of Increased Commercialization of Subsistence Agriculture on Production, Consumption, and Nutrition." Washington DC: International Food Policy Research Institute, 1989.

Agribusiness Competitiveness across National Boundaries

Larry Martin, Randall Westgren, and Erna van Duren

International competitiveness has become an extremely important topic in Canada. It is high on the political agenda because it is high on the economic agenda. It is particularly important for Canada's agri-food industry. The Canadian food sector evolved during the past half century behind a roughly 20% protective tariff wall, which is being removed by the Canada–U.S. Trade Agreement (CUSTA). The sector must adjust.

While competitiveness is a major issue and topic of discussion, it has not been well defined or measured. Moreover, untangling the web of causality between elements of public policy, private management strategy, and the food industry's competitive state is fundamental. Thus, in this paper we develop a framework for assessing the competitive state of an industry. The objectives are to (*a*) develop a framework for assessing an industry's competitiveness, (*b*) report on the competitive state of five food-processing industries, and (*c*) assess the public policy implications that arise from application of the framework for these five industries.

The Framework

The framework builds on the definition of competitiveness by Canada's Task Force on Competitiveness in the Agri-Food Sector, "The sustained ability to profitably gain and maintain market share," and on research performed in other studies by the authors (Martin et al. 1991a,b; van Duren and Martin; Westgren, Martin, and van Duren).

This definition provides two concepts that can be used to measure and monitor competitiveness: profits and market share. Also it implies that the assessment of competitiveness must be comparative. Figure 1 points out that market share and profit are the relevant measures. Figure 2 shows specific variables that can be used to represent them.

Value added for industries that buy raw materials, process them, and resell them in different forms measures the activity in such industries and is an indirect method for measuring profits. Value-added data are available on a comparable basis in Canada and the United States. By expressing value added for an industry in one country compared to another, relative to the number of workers, sales, expenditure on wages, and the number of establishments, one gets a very thorough, if somewhat indirect, notion about the industry's profit performance (fig. 2).

There are many potential measures of market share (fig. 2). We primarily rely on the net export orientation ratio, the difference between an industry's exports and its imports, expressed as a percentage of the average of domestic production and consumption. The sign of this measure indicates immediately whether an industry is a net exporter or importer, and its absolute size indicates the relative importance of trade.

The factors contributing to competitiveness in the lower part of figures 1 and 2 are taken from neoclassical economics, industrial organization, and the strategic management literature. Because of Canada's current emphasis on public policy to encourage competitiveness, we begin by thinking of four sets of factors that contribute to competitiveness: factors controlled by individual firms, those controlled by governments, those that are quasi-controllable, and those that are uncontrollable. In many cases the policies of government limit, through explicit or implicit means, the choice of strategy and/or the implementation of strategy that firms can undertake.

Larry Martin is Distinguished Professor in the George Morris Centre; Randall Westgren is chairman, Department of Agricultural Economics, McGill University; Erna van Duren is an assistant professor, Department of Agricultural Economics and Business, University of Guelph.

Hence, the pursuit of competitiveness is a partnership between public policy and management strategy, or private policy. Input prices, demand conditions, and the international trade environment are under the quasi-controllable category because they are either outside the direct influence of an individual country's government or, as with demand conditions, they can only be somewhat affected by the actions of either companies or governments. The most obvious uncontrollable factors are natural environment and climate.

The interaction of the factors outlined at the bottom of figure 1 combine to produce what we call "the drivers" of competitiveness that are outlined at the bottom of figure 2. The drivers are, generally, interactive. They provide particular concepts on which to focus in determining what causes the competitive state of an industry. Technology, productivity, inputs and cost, industry structure, and demand conditions are factors that flow directly from economics and industrial organization theory. Our concern about productivity is with the inherent productivity of the manner in which businesses are structured. It has to do with whether the appropriate combination of plant, equipment, technology, and human resources exists.

The inclusion of products and linkages explicitly recognizes the contributions of strategic management writers (e.g., Porter 1985, 1990; Ohmae; Peters). This literature is pregnant with lessons that businesses are learning about the manner in which they combine their resources, the quality and distribution channels they choose through which to distribute their products and, particularly, the use of strategic alliances with their customers or suppliers. These are increasingly important determinants of the ability to be competitive, particularly in a fast changing and global marketplace. Economic theory and industrial organization do not handle them at all well.

Application of the Framework to Five Industries

The authors have been involved in two studies on behalf of Industry, Science and Technology Canada and the Ontario government, which are concerned with assessing the competitive state

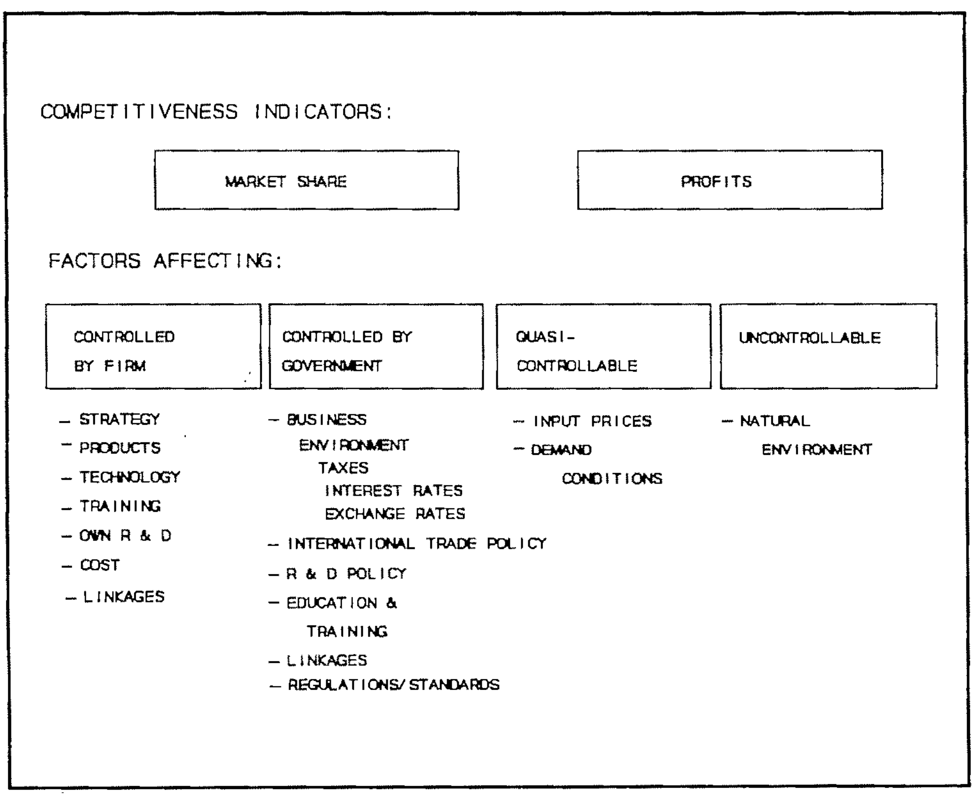


Figure 1. Competitiveness indicators and factors affecting them

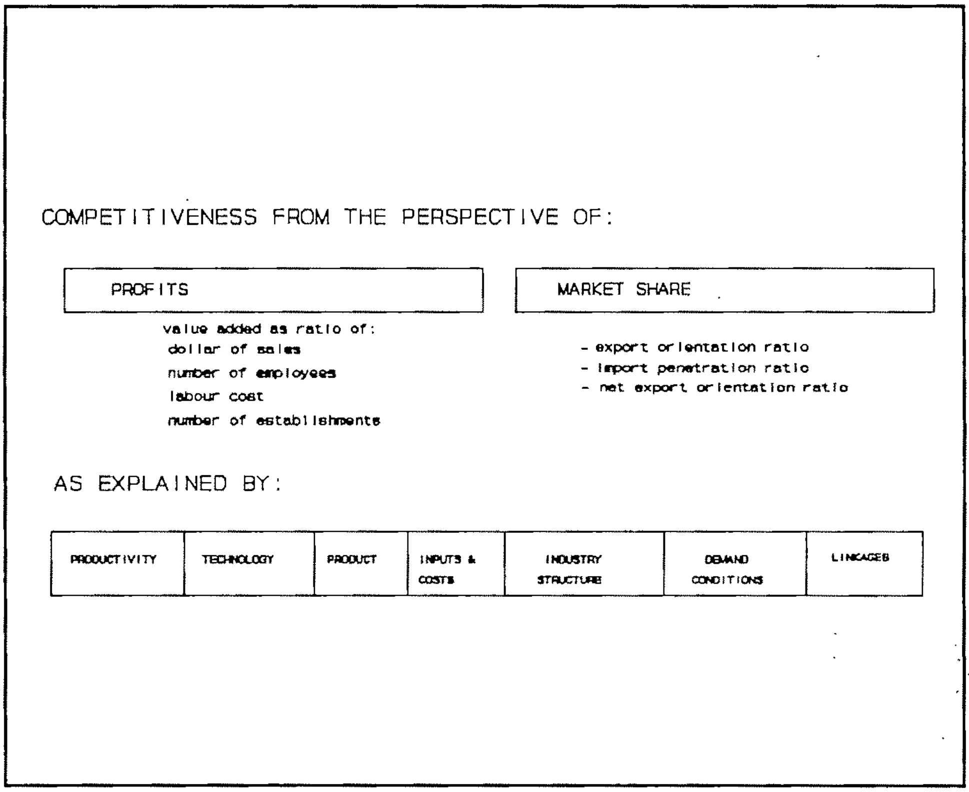


Figure 2. Competitiveness variables and their drivers

of five food-processing industries. The length for the current paper limits us to the following observations from these studies.

The Competitive State

The five processing industries include poultry, fruit and vegetable, wheat-based products, dairy, and red meat. All data used in assessing competitiveness were taken from secondary sources (Statistics Canada until 1988; the Department of Commerce for the U.S. until 1987). Hence, the major limitation of this study is that, because of the slowness with which official statistics are reported, we can say nothing about how relative competitiveness has changed since the beginning of CUSTA. This is an important weakness for us in Canada.

The results are reported in table 1. These are summarized from the basic work but represent the general outcome of the analysis.

Poultry. Primary production in the poultry industry in Canada is controlled by farmers' marketing boards which have the power to limit production and to establish prices unilaterally, based on production costs. Canada's tariffs have been relatively high but are being removed under CUSTA. However, the more binding Canadian import quotas are not being removed. The U.S. industry is characterized at all levels from primary production through primary and secondary processing by a high degree of vertical integration. Hence, the type of control in the U.S. industry is considerably different than in Canada's.

Compared to the following industries, poultry processors in both Canada and the United States add relatively little value to their purchased raw materials. Their value added as a percentage of sales increased marginally from just over 20% to about 25%. Canada's processors added slightly less than American processors. When one looks at value added per worker, the Canadian industry held a considerable advantage at the beginning of the 1980s, but much of that advantage eroded before the end of the decade. This probably reflects more adjustment toward larger-scale plants in the United States during the decade than occurred in Canada.

Interestingly, Canada's processing industry began the decade at a disadvantage to the U.S.

Table 1. Summary of Competitiveness Measures

	Value Added Per									
	Dollar Sales		Worker		Dollar Wages		Plant		Net Export Orientation	
	1980	1987/8	1980	1987/8	1980	1987/8	1982	1987/8	1982	1987/8
	(%)		(Real 000 $)		(%)		(Real Mil $)		(Ratio, %)	
(a) Poultry										
Canada	20.8	24.4	42.9	45.1	192	211	3.8	4.6	−2.0	−2.5
U.S.	22.3	27.6	31.1	41.6	241	264	6.2	12.0	3.2	2.8
Difference	−1.5	−3.2	11.8	3.5	−49	−53	−2.4	−7.4	−5.2	−5.3
(b) Fruits and Vegetables										
Canada	34.7	38.9	72.9	101.9	369	488	4.8	6.0	−18.2	−14.5
U.S.	39.7	47.5	79.6	132.1	428	622	8.6	12.0	−1.1	−2.7
Difference	−5	−8.6	−6.7	−30.2	−59	−134	−3.8	−6	−17.1	−11.8
(c) Wheat-Based Products										
Canada	42.5	46.3	63.0	71.0	284	302	1.1	2.8	6.3	1.6
U.S.	49.9	61.2	121.0	193.0	511	646	7.3	9.6	−0.3	−0.3
Difference	−7.4	−14.9	−58	−122	−227	−344	−6.2	−6.8	6.6	1.9
(d) Dairy										
Canada	18.8	24.6	82.0	130.0	395	480	3.0	3.1	0.0	0.0
U.S.	21.6	24.9	101.0	138.0	595	660	5.1	5.0	−0.2	−0.2
Difference	−2.8	−0.3	−19	−8	−200	−180	−2.1	−1.9	0.2	0.2
(e) Red Meat										
Canada	17.1	20.9	69.0	70.0	258	276	3.1	3.3	7.8	7.3
U.S.	14.8	15.7	111.0	138.0	289	359	4.1	4.6	0.0	−3.9
Difference	2.3	5.2	−42	−68	−31	−83	−1	−1.3	7.8	11.2

industry in terms of value added per dollar of expenditure on wages. The apparent discrepancy between value added per worker and value added per dollar of wage expenditure lies in the fact that Canadian wage rates are considerably higher in this industry than are U.S. wage rates. Thus, the advantage Canada has in terms of productivity per worker has apparently been distributed to the workers. Value added per plant is considerably higher in the United States than in Canada. It also increased very substantially in the United States during the decade. This confirms the earlier suggestion that the relatively greater gain in value added per worker by the United States is associated with a faster rate of consolidation and plant expansion in the U.S. industry.

International market share data are relatively uninteresting for the poultry industry because of Canada's supply management program.

Fruit and Vegetables. Primary production in horticulture is generally carried out through contracts, marketing agreements, or marketing orders in both countries. In Canada, contracts are negotiated between farmer-controlled marketing boards and processors. U.S. contractual arrangements are negotiated in various ways, depending upon location and commodity. Much of the horticultural industry in Canada has enjoyed relatively high protection under the situation prior to CUSTA (tariffs of approximately 15% to 20%). These are being removed at a rate of 10% per year.

Table 1 indicates that the Canadian processing industry began the 1980s at a disadvantage to its U.S. counterpart and ended the decade at a bigger disadvantage. Canada's value added was lower per unit of each denominator in 1980 and its performance improved during the decade. However, in each case the U.S. improvement was greater, so that Canada ended the decade at a larger deficit than was the case at the beginning. Once again it is apparent that the U.S. industry increased its value added per plant by a much greater amount than did the Canadian industry during this period. This suggests the fundamental problem of the Canadian industry is not its relatively low labor productivity. Rather it is relatively low capital productivity which, when interfaced with labor, limits the productivity of workers. Interestingly, despite the performance on the value-added measures, Canada's market share improved marginally during the period. While Canada is a major net importer of processed horticultural products, the net export orientation ratio declined, indicating a slight move toward self-sufficiency.

Wheat-based products. Wheat-based products industries are in a similar situation as horticultural products. Prior to the trade agreement, Canada indulged in a two-price wheat scheme that maintained domestic wheat prices at a relatively high level during most years. Passage of CUSTA meant removal of the two-price wheat scheme. However, until early in 1990, pricing behavior by the Canadian Wheat Board continued to maintain basic wheat prices at a relatively higher level in Canada than in the United States. In addition, Canada has effectively precluded imports of U.S. wheat into Canada through the use of import permits. As a result of CUSTA, Canada agreed to stop using import permits when subsidies to U.S. wheat producers were reduced to the level in Canada. This happened in 1991.

The measures of competitiveness for the wheat-based products processing industry are similar to those for horticultural processors. The major difference is that, if anything, the Canadian processing industry lost even more ground relative to its U.S. competitors during the 1980s. There is a marked difference in value added per plant. This reflects the much greater average size of plant in the United States. While there are several SIC categories within this industry group, the flour milling industry is representative. During the late 1980s, U.S. flour sales per plant were ten times those in Canada.

Market share data for wheat-based products is consistent with the value-added measures. Canada's net export orientation ratio declined from being relatively large and positive to being negligible.

Dairy. Primary dairy production is controlled by marketing boards in Canada. Fluid milk is controlled by provincial marketing boards. Industrial milk is controlled in terms of production, farm price, and allocation to plants by the Canadian Dairy Commission. The U.S. system of control is different, but with comparable results. Both dairy industries are the recipients of considerable subsidy from consumers, either through direct transfers or by conferring monopoly powers on producers.

Under CUSTA, both countries remove their tariffs. However, the United States continues to control imports using quantitative restrictions.

To date, Canada also continues to use this technique, although Canada has been reprimanded by GATT following a U.S. appeal of essentially the same quantitative restrictions on imports of dairy products to Canada as the U.S. uses.

The value-added measures for the dairy industry are considerably different than the other industries. On each measure, Canada began the 1980s behind the United States and gained relative to the United States during the decade. The major discrepancy between the two countries lies in value added per dollar of expenditure on production wages, where Canada continues to lag substantially. Dairy processing, like poultry processing, has higher wage rates in Canada than in the United States. This is unlike the other three industries analyzed. Because of the plethora of controls in the dairy industry for both countries, the market share data are not particularly interesting.

Red meat. Red meat markets in both countries are characterized by open markets at the primary production level. There were few tariffs on live animals or meat products by the two countries before CUSTA. Therefore, little has changed officially as a result of CUSTA. But, there has been considerable trade friction between the two countries, especially on pork because of Canada's alleged subsidies. These have resulted in U.S. countervailing duties on hogs and, more recently, on pork until the improved appeal process under CUSTA caused the duty on pork to be removed.

The Canadian industry led the U.S. industry in value added per dollar of sales in 1980 and increased its lead during the decade (table 1). However, the Canadian industry was at a disadvantage in terms of value added per worker, dollar of wage expenditure, and plant. This disadvantage increased during the decade. This leaves a picture of an industry that, in Canada, does a good job of adding value with the basic facilities and resources at its disposal. However, the lower value-added measures per worker, dollar of wage expenditure, and plant suggest there are insufficient resources or insufficient resources of the appropriate type or scale in the industry. There was little change in relative market shares during the decade.

The outcome of the foregoing analysis suggests that as the Canadian food industry entered CUSTA in 1989, it was at a considerable competitive disadvantage in all areas with the possible exception of dairy processing.

The Competitiveness Drivers

There is little secondary information available that allows one to say much about the relationship between the drivers and the state of competitiveness. However, the following points can be summarized. First, with the exception of dairy processing, Canada's processing plants are considerably smaller than those in the United States. Second, there is, in general, a slightly higher degree of concentration in Canada. However, with the advent of CUSTA, concentration within the Canadian market is, in our view, a largely irrelevant factor. What is more relevant is that Canadian plants are small and their investment in research and development and, apparently, in technology transfer is relatively low. This leads to the conclusion that the inherent productivity of the Canadian industry is lower than the U.S. industry.

Another factor we know something about is demand conditions. We computed the average per capita share of caloric consumption that consumers in both countries obtain from each of the major food groups represented by the processing industries studied. Our conclusions were that demand in Canada is very strong for horticultural and wheat-based products both absolutely and relative to the United States. Demand for red meat is declining in both countries. Demand for dairy products is basically flat. Demand for poultry is growing quite substantially in both countries.

It appears that the relative demand situation is not a major determinant of the relative competitive state of these industries. It is noteworthy that (*a*) the demand for wheat-based products in Canada appears to be stronger than in the United States and (*b*) that Canada would appear to have a natural advantage in producing wheat. Yet, the performance of Canada's wheat-based products industry is quite poor. Thus, the industry does not appear to fit Porter's model.

A fourth driver about which something can be said is the inputs and costs component. Again, to summarize:

(*a*) Wage rates in the processing industries for horticultural products, wheat-based products, and red meat are lower in Canada than in the United States.

(*b*) Canada has an advantage in energy costs. Comparing energy costs in southern Ontario with those in most U.S. locations indicates that Ontario has a 20% to 25% advantage in both electricity and natural gas.

(*c*) Canada has an advantage in sugar prices.

The United States has a protective sugar policy, and Canada trades on the world market. Thus, Canada has enjoyed at least a 9¢ per pound advantage on sugar prices during the past decade, but this has been offset to some extent by U.S. restrictions on imports of products with sugar in them.

(*d*) Canadian raw material prices are higher in general than is the case for the U.S. processing industries. Our analysis shows that milk, poultry, wheat, and a number of vegetables have been higher priced in Canada than in the United States. There are some exceptions to this and, in some cases, Canadian marketing boards negotiate different prices for raw materials going to different end uses.

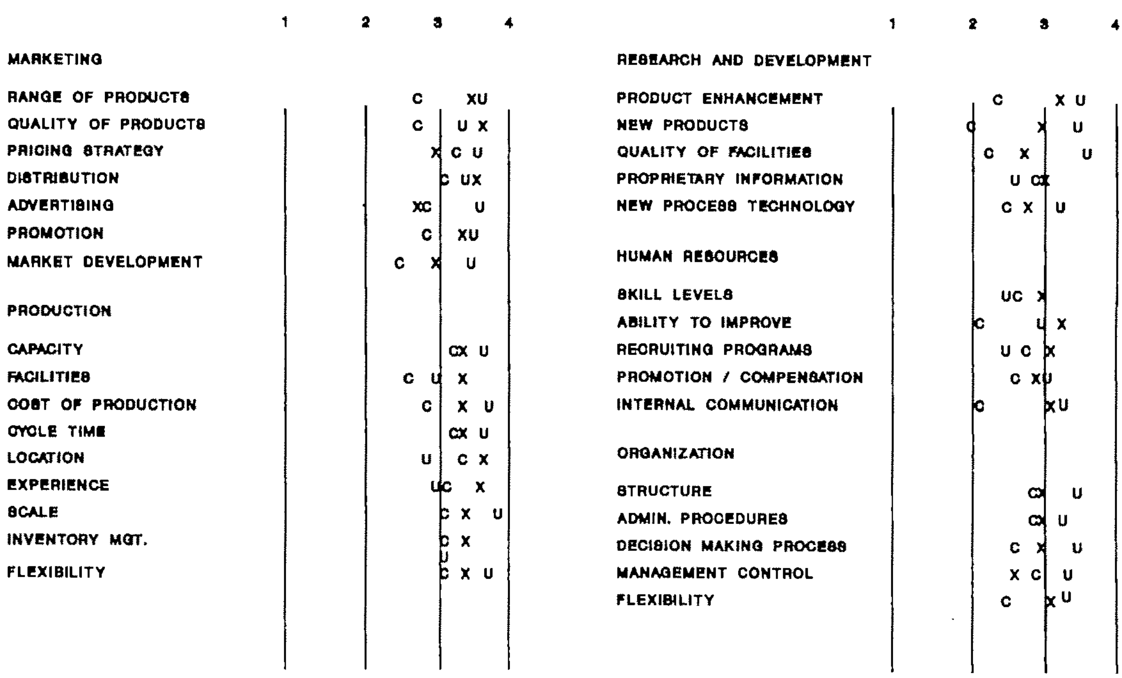
The foregoing implies that, on average, Canada has cost disadvantages: higher prices for raw material usually swamp lower prices for other inputs. In a series of resource cost coefficients that were calculated, it is clear that the total processing costs, given fixed processing technology, are approximately 10% to 30% higher for Canadian manufacturers of food than for U.S. manufacturers.

It is difficult to say much about products, linkages, technology, and productivity from secondary data. Therefore, we developed a questionnaire which was administered to approximately twenty senior managers in three of the food-processing industries (poultry, wheat-based products, and horticulture). Part of the questionnaire focused on five major aspects of the business environment that influence company strategy and competitive advantage, which were further divided into approximately thirty individual aspects of strategy.

The five major areas are marketing, production, research and development, human resources, and organization. Each manager was asked to rate on a four-point scale each of the aspects of competitiveness. They were asked to rate their own company, their major Canadian competitor, and their major U.S. competitor.

Figure 3 contains a summary of the responses to the questionnaire. If the rating in figure 3 falls more than half way between three and four, it means that the average rating was above 3.5. This means that managers felt that the appropriate rating was very close to excellent. Thus, four is excellent and one is poor.

There are a number of very interesting conclusions from the figure. First, with the exception of those elements under human resources,



Note: X is Canadian managers' self reported scores
U is perceptions of American competitors
C is perceptions of Canadian competitors

Figure 3. Industry profiles

Canadian food processors generally rate their U.S. competitors higher than themselves or their best Canadian competitors. This is true for products and marketing, where the U.S. competitors are rated highest in five of the seven categories and very close to the own company in the other two.

It is not surprising that Canadian processors rate their U.S. competitors higher in most of the production categories. It is clear that Canadians feel the Americans have considerable advantage in terms of capacity, cost of production, cycle time, and scale. They rate themselves higher in terms of facility location and experience. Most of those who answered considered the question about location to be relative to the Canadian market. This is a good indication of their international orientation.

It is particularly interesting that Canadian managers give their U.S. competitors an advantage in flexibility. It is widely believed that Canadian plants are, by necessity, more flexible within the plant because of the fact that Canada has smaller plants and many segmented markets. Most managers agreed that on a plant-by-plant basis, Canadian processors are superior. But, they also point out that many major U.S. competitors have more than one plant. Therefore, U.S. firms can obtain flexibility by optimum use of their networks. This is done with less down time and, therefore, the Canadians give the United States an advantage.

Canadian managers give their U.S. counterparts a major advantage in all but one of the categories under research and development. In the one that is an exception (ability to protect proprietary information), most managers rated it as unimportant because it is so difficult to retain proprietary information in this industry.

As can be seen, the area of greatest relative strength for the Canadian industry was felt to be in human resources. A number of senior managers suggest that if Canada is going to be competitive in the future, it will have to be done with the relatively higher skill levels and relatively higher quality of human resources that are felt to exist in Canada.

Conclusion

This paper has developed a framework that can be used to analyze relative competitiveness. It has illustrated the application of this framework to five food-processing industries in Canada and the United States. Our conclusion from the value-added and market share variables that have been defined as indicators of competitiveness is that four of the five industries in Canada declined in relative competitiveness during the 1980s. In general, the analysis shows that the food-processing industry in Canada was not in a particularly strong condition as it entered CUSTA.

The framework developed relies on seven "drivers" of competitiveness that are examined to determine the cause of an industry's competitive state. These were examined using both secondary and primary data. We conclude the following:

(*a*) Canadian productivity is lower, in part because of its smaller plants and also in part because of its lower use of technology and research and development.

(*b*) As indicated above, managers in Canada feel that the food industry is far behind its U.S. counterpart in all aspects of research and development.

(*c*) Canadian managers give a fairly substantial advantage to U.S. companies in terms of products and marketing.

(*d*) While Canada has some advantages in terms of processing input prices, they are generally overwhelmed by higher commodity prices in Canada.

(*e*) Concentration is marginally higher in Canada than in the United States. However, this is not likely a major factor, especially given that trade barriers are being removed and, therefore, Canadian companies must compete as part of a North American market.

(*f*) While there are substantial differences in demand conditions among the products, there does not seem to be a particular correlation between demand conditions and relative competitiveness of industries. For example, the industry that should most obviously be competitive in Canada based on both demand and supply conditions is wheat-based products. However, it appears to be the one that slipped the most in competitiveness during the past decade.

Putting these together can lead to another conclusion that the Canadian sector is at a disadvantage on most of the drivers. It is clear from the analysis that the Canadian industry must adjust if it is to survive. The most fundamental factor that is required for change is that firms must increase their productivity, especially of capital. There are two ways this can occur. One way is to develop toward large plants with economies of size that feed mass markets. The problem with this is that Canada has small plants, it faces considerable trade barriers from the United

States whenever a Canadian industry is successful in exporting to that country, and it flies in the face of much of current management thinking that suggests markets are becoming increasingly segmented and that suppliers will need to be increasingly flexible to appropriately serve the segments in the future.

The second alternative is to build on Canada's strengths. There does appear to be a strength in terms of flexibility of plants, if not of companies. Canadian managers feel that there is an advantage in human resources. There are advantages in energy and, to some extent, labor costs. Moreover, some of the discrepancies in commodity prices are being reduced by CUSTA. All of these suggest that perhaps a more realistic path toward improvement of productivity in this industry is to move toward producing high value-added products that have an international orientation, that require high human resource skills and relatively intensive use of energy in their production.

There is, of course, a middle ground. In some industries or some parts of an industry, it may be appropriate that mergers and expansions occur so that economies of size can be realized. This would most likely be the case for those parts of an industry that are involved in producing a commodity, i.e., flour, tomato paste, beef and pork carcasses or even boxes, and relatively low value-added frozen and canned horticultural products. In other industries or parts of the industry, the second approach might be appropriate.

The choice of adjustment paths for the Canadian sector will have considerable implications for the type of policy pursued by both firms and government. There can be no question that the Canadian Government must move and move rapidly to make the right choices to encourage rapid adjustment and improvement in productivity in the food industry. Public policy decisions must be driven by the specific needs of the market development opportunities in each industry. Private business policy needs to be aimed at exploiting individual company endowments and the segmented markets they can best serve, i.e., they should exploit their potential economies of scope. A confluence of private and public policy is required for Canada's food industry to prosper in the future.

References

Martin, Larry, Erna van Duren, Randall Westgren, and Marc Le Maguer. *A Review of Ontario's Food Processing Industry*. Report prepared for the Ontario Ministry of Agriculture and Food, Toronto, 1991a.

——. *The Competitiveness of Canada's Food Processing Sector*. Report prepared for Industry, Science and Technology Canada, Ottawa, 1991b.

Ohmae, Kenichi. *The Borderless World: Power and Strategy in the Interlinked Economy*. McKinsey & Company.

Peters, Tom. "Prometheus Barely Unbound." *Academy of Management Executive*, no. 4 (1990), pp. 70–84.

Porter, M. *Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Macmillan Co., 1985.

——. *The Competitive Advantage of Nations*. New York: Macmillan Co., 1990.

Task Force on Competitiveness in the Agrifood Industry. *Growing Together*. Report to the Minister of Agriculture, Ottawa, June 1990.

van Duren, Erna, and Larry Martin. "Assessing the Competitiveness of Canada's Food Processing Industry." Paper presented at a NE-165 Conference, Alexandria VA, June 1991.

Westgren, Randall E., Larry Martin, and Erna van Duren. "Measurement of Competitiveness Among Agribusiness Sectors Across National Boundaries." Paper presented at the Third Annual Meeting of Western Regional Coordinating Committee-72, Agribusiness Research Emphasizing Competitiveness, Las Vegas NV, 10–11 June 1991.

Information Technology, Coordination, and Competitiveness in the Food and Agribusiness Sector

Deborah H. Streeter, Steven T. Sonka, and Michael A. Hudson

As business managers search for strategies to improve the competitive position of their firms, information technology is playing an increasingly crucial role. While much of the literature on competitiveness has examined how such technology supports the strategic goals of the firm by lowering costs, raising barriers to outside competitors, or facilitating the differentiation of products, relatively little attention has been devoted to the role technology plays in shaping the relationship between players in a production-marketing spectrum.

It is the goal of this paper to explore the topic of technology, coordination, and competitiveness in the context of the agribusiness sector. Specifically, we will argue that in an increasingly consumer-oriented business environment, information technology not only has enhanced but has hastened coordination strategies between various levels of the sector. Furthermore, these coordination strategies would not necessarily have evolved as a result of the existing price signals or market structure.

The first section of the paper addresses definitional issues along with a literature review. The review includes both contributions from the agricultural economics field and research from the business literature on competitiveness. In the second section of the paper, we argue that as a result of information technology, the agribusiness sector has become increasingly focused on the consumer, forcing retailers to shift their marketing strategies. Illustrations of how consumer demands are passed down through the producer-consumer chain and a discussion of conditions which might enhance or inhibit information-based coordination strategies are discussed in the third section. In the fourth section, we discuss implications for the agricultural economics profession. The conclusions which result from the framework we suggest are presented in the final section.

Background and Perspective

Before exploring the main theme of the paper, there are some important definitional issues to resolve. The first is to clarify the term information systems, the second is to outline more precisely our view of the agribusiness sector, and the third is to explain what is meant by competitiveness.

What is considered an information system varies widely in the literature, but we will use the general definition provided by Davis and Olson: "an integrated, user-machine system for providing information to support operations, management, analysis and decision-making functions in an organization" (p. 6). It is important to emphasize we are interested primarily in computerized information systems, and, furthermore, we will focus on those technologies which may enhance the transfer or sharing of knowledge between two entities.

A second area of semantic difficulties arises from the use of the term agribusiness. The traditional view of agribusiness considered only activities "beyond the farmgate." However, we adopt an emerging view introduced by Sonka and Hudson and elaborated by Hudson in which the food and agribusiness sector is a chain of interrelated activities including genetics and seed stock firms, input suppliers, agricultural producers, merchandisers, processors, retailers, and consumers supported by firms providing various services, financing, and research and development. The broad view of the agribusiness sector

The authors are, respectively, an assistant professor of agricultural economics at Cornell University; a professor of agricultural management, University of Illinois; and an associate professor, Bruce F. Failing, Sr., Chair of Personal Enterprise, Cornell University.

includes not only production but also acknowledges the increasing importance of consumers, a point to be stressed in the next section.

A final definitional issue is to clarify what is meant by competitiveness. According to Porter, a competitive strategy is the "search for a favorable competitive position in the industry . . . to establish a profitable and sustainable position against the forces that determine industry competition" (p. 1). In this paper, we argue that players need a new vision about potential competitive strategies because of changes in the forces that determine industry competition in agribusiness. For example, producers have typically viewed lowering costs as the main avenue for achieving competitive advantage, but we suggest information technologies may provide additional means for establishing a profitable and sustainable position.

In exploring issues of information technology, coordination, and competitiveness, it is important to acknowledge a broad range of literature on related topics. For example, Mighell and Jones delineated a conceptual framework to examine vertical coordination, and various authors have highlighted the need for a more systematic examination of the food and fiber sector (Shaffer, Shrader) and the existing goal conflicts which might inhibit coordination (Purcell). While data problems plague studies of coordination between subsectors, some system-wide research has suggested vertical integration will increase in the future (Kilmer). On the information systems side, there has been some work on scanner data (McLaughlin and Lesser, Capps), but it has focused on in-store uses of the data rather than coordination issues. While this literature serves as a useful backdrop, it fails to focus on the effects of information technology on trends in coordination.

On the other hand, most research on information systems and competitiveness addresses the strategic uses of information systems but does not emphasize coordination issues. For example, Porter's "value chain" concept focuses attention on the role of information technologies in lowering costs, raising barriers to entry, and/or differentiating products. It does not address directly the role technology may play in enhancing coordination between market players. Strassmann focuses on the interaction between management skills and the role information systems play in supporting the strategic aims of the firm but does not directly address issues of how technology changes interfirm relationships.

Konsynski and McFarlan are among the few authors writing on competitiveness who do link information technology and coordination issues. Focusing on the nonfood sector, they explore various "information partnerships" between market players which allow for more efficient and profitable coordination. An important conclusion of their research is that information partnerships can provide a strategic advantage for market players who have the vision to identify unexploited opportunities. Streeter and Hudson apply the Konsynski-McFarlan framework to the food and agribusiness sector, identifying various potential partnerships. In a different but related view of how information technology plays a role in interaction between market players, Ives and Mason describe a framework for improving customer service through the use of information technology.

The individual themes of competitiveness, information systems, and coordination abound in the work cited above, but there is a need to link them together more clearly. In this paper we present a framework in which information systems impact competitive advantage and coordination specifically within the agribusiness sector.

A Consumer-Oriented Agribusiness Sector

Historically, the commodity-oriented agribusiness sector has been driven by economic forces to produce at maximum efficiency while maintaining low costs. Price signals, defined at the level of relatively coarse grades and standards, were the primary form of information communicated throughout the market channel. The result has been a system which is remarkably effective at converting undifferentiated commodities into relatively low-cost food.

Despite its cost effectiveness, the commodity-oriented agribusiness sector is undergoing change, inspired in part by the evolution of a more demanding and differentiated food consumer. In response, retailer strategies have emerged which focus on improving service to the end consumer. As Ed McMillan, chief executive officer of Purina Mills notes, "for the first time in the history of American agriculture, the end consumer—not the producers or packers—now drives the entire food chain."

Two alternative views of the food and agribusiness sector are presented in figures 1a and b. In the more standard view (fig. 1a), retailer strategies are focused on what was characterized in Packard's classic *Hidden Persuaders* as ma-

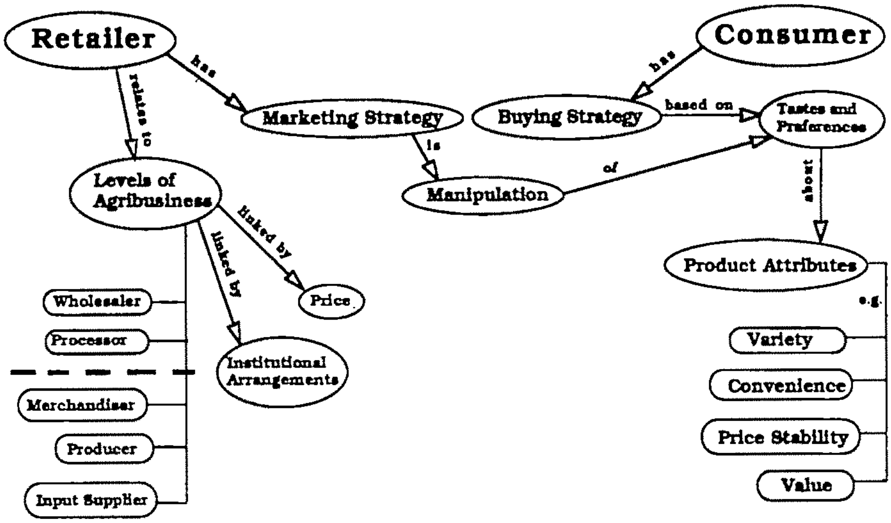


Figure 1a. Standard view of coordination in the food and agribusiness sector

nipulation of consumers' tastes and preferences. A contrasting view, more characteristic of strategic behavior of retailers in the 1990s, is shown in figure 1b, where the energies of the retailer are directed toward discovering consumer preferences and adapting product attributes in response to consumer demands. Reflecting the focus on the consumer tastes and preferences, terms such as "niche marketing" and "micromarketing" have become prevalent in the marketing and advertising literature. Rapp and Collins have gone so far as to suggest that "individual marketing" will be the wave of the future, essentially reducing the market to segments of one. In a similar tone, Peters (p. 73) characterizes the marketing battleground as having shifted from "more,

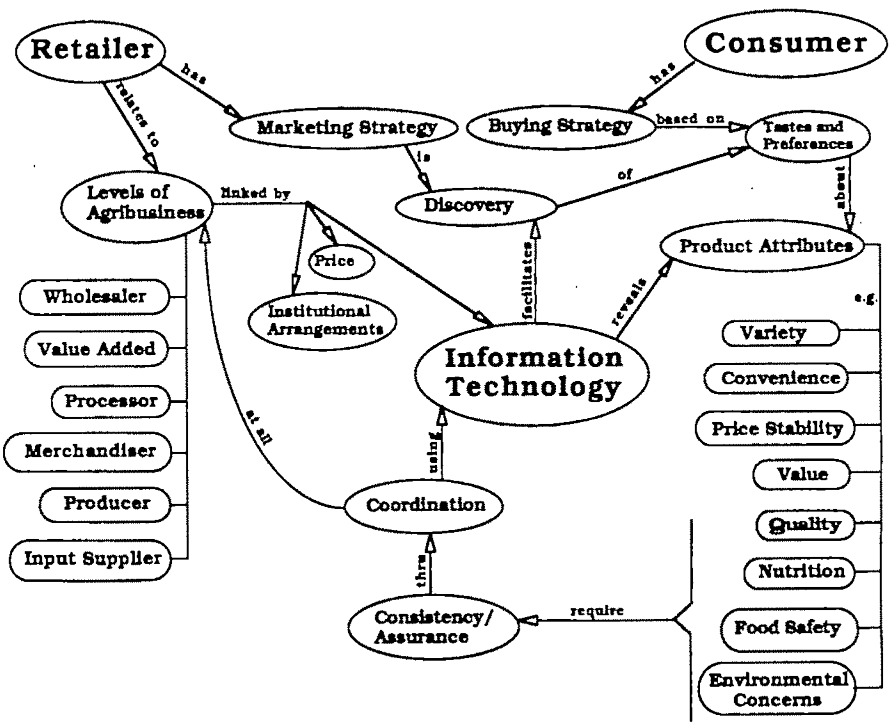


Figure 1b. An alternative view of coordination in the food and agribusiness sector

more, more for bigger, bigger, bigger markets to better, better, better for ever more finely diced markets."

There are several ways in which information technology has facilitated, if not caused, the shifting of marketing efforts toward the discovery of consumer preferences, as shown in figure 1b. Information technology (and legal disclosure requirements) have made it easier for the consumer to see a wider range of product attributes. Thus, in figure 1b information technology is depicted as revealing additional product attributes which were not always apparent to consumers. Where buying decisions were once made on such aspects as variety, convenience, price stability, and value (see fig. 1a), now consumers can also evaluate additional characteristics (see fig. 1b) which were previously experienced only indirectly, such as product quality (e.g., how much milk in a slice of cheese), nutrition (e.g., fat and cholesterol content), food safety (e.g., what additives are present), and environmental aspects (e.g., whether an item is organically grown, or whether the tuna harvest resulted in a dolphin being killed).

Armed with a new awareness of product attributes, consumers are afforded at least the illusion of increased control over what they consume, causing retailers to scramble to showcase their products as having the desirable characteristics. To reflect this trend, information technology in figure 1b is shown as facilitating the discovery by retailers of the tastes and preferences of consumers. Technologies such as scanning and couponing with individual household identification numbers (IDs) allow retailers to track buying strategies of consumers more accurately than ever. An example of this trend in agribusiness is the formation of the Associated Marketing Services (AMS) by a European group of national grocery chains. An aggressive user of scanning technology, AMS has a goal of developing profiles of the European food consumer in the post-1992 business environment. Frito-Lay's use of hand-held computers and electronic information transfer by its sales force is another example of more aggressive use of technology to monitor consumer behavior.

So far, discussion has been limited to the relationship between the consumer and retailer. However, some of the product attributes which information technology has made transparent to the retailer cannot be created during the marketing process but rather must be assured from the beginning of the production-marketing chain. As shown at the bottom of figure 1b, quality, nutrition, food safety, and environmental concerns are affected at each step of the continuum which begins with the input provider and ends with the consumer. This puts into question the traditional view that product differentiation is the responsibility of the marketing subsector (those players above the dashed line in fig. 1a), and not the production subsector (those players below the dashed line in fig. 1a). In the alternative view shown in figure 1b, the sector is shown without segmentation between subsectors. Furthermore, information technology is shown as a means of coordinating activities across levels in order to assure certain product attributes.

Retailers seeking to respond to consumer preferences on newly visible attributes must find ways to pass the consumer signal down the chain. In turn, players at other levels in the food and agribusiness sector may increasingly find strategic opportunities to serve the demand for particular product attributes. Where activities between levels in the sector were once linked through institutional arrangements and/or price (fig. 1a) they now also may be coordinated through information technology (fig. 1b).

An important point to note is that the two frameworks presented in figures 1a and b are not mutually exclusive. For example, there may be many cases in which product differentiation early in the food-marketing chain is not feasible. Alternatively, consumers may not be willing to pay a high enough premium to justify differentiation at the farm (or some other) level. The challenge is to recognize where the alternative framework may be more appropriate and to seek out opportunities for competitive advantage through coordination.

Coordination and Information Technology

To respond to a more consumer-oriented environment, players in the agribusiness sector may need to explore how information technology can facilitate the coordination activities needed to assure particular product attributes. However, it is important to recognize that existing linkages between various levels of the agribusiness sector are conditioned by market structure. Until now, within the existing market structures, input and output prices have been relied upon as signals to coordinate activities among various levels of the sector. However, in the future, information technologies may facilitate new strategies among players by providing better information flows and by facilitating coordination of production and

marketing activities. Examples of existing coordination strategies which rely heavily on information systems will help illustrate how this occurs.

Pioneer's *Better Life Grains®* and Frito-Lay's *Frito Corn Chips®* are two examples where information technology is currently in use to assure product quality throughout the agribusiness chain. Pioneer seeks input suppliers who use a particular technology to tailor-make a seed which grows a product with specific attributes. Producers are then required to provide specific production assurances which allow the processor to label the product as having a specific set of nutritional attributes. Pioneer stands behind the attributes and accepts an implicit role as the enforcer in the process, and information technology is what provides the linkages. Likewise, Frito-Lay contracts with producers for specific types of corn. The processed commodity is tracked all the way through the market channel on a bag-by-bag basis to assure product quality.

Additional examples can be found for livestock products. Cattle producers can receive a premium from certain companies for producing "antibiotic-free" animals. *Certified Angus Beef®* is another example of quality assurance that must be guaranteed from conception to consumption. In the poultry industry, which is already highly integrated, information technology makes it possible to monitor day-to-day operations to assure appropriate feed consumption and optimal delivery times.

Given the existing uses of technology to coordinate throughout the sector and assure consumers of goods with particular attributes, how can we identify untapped opportunities for similar competitive strategies elsewhere in the agribusiness sector? One approach, which borrows from the framework set out by Ives and Mason, is to ask the following questions: (*a*) Can the product be made to order or customized? (*b*) Can the product be traced after purchase and if so, from what level? (*c*) Is there a way for players at different levels to profile their customers? (*d*) Can the terms of sale be negotiated to reward producers and processors who respond to the consumer-driven environment? An affirmative answer to these questions suggests potential opportunities. Three major forces determine the answers to these questions: market structure, existing production technology, and the state of information systems.

Differences in market power may make information sharing unpalatable or impossible (see Konsynski and McFarlan for examples). In addition, antitrust considerations, which are conditioned by existing market structures, could pose barriers to competitive strategies involving coordination strategies. Finally, the reward system for coordination is affected by the relative market power of various players, which determines whether the terms of sale are stipulated or negotiated. Even where coordination is made feasible through information technology, it is unlikely to occur without a profit incentive.

Existing production techniques can greatly enhance the chance for using information technology to coordinate among players in the agribusiness chain. For example, through biotechnology, particular inputs can be highly tailored. In such circumstances it will be possible to assure quality or other characteristics from the input end of the agribusiness sector. Technology which enables producers to monitor fertilizer and chemical application to a very high degree of accuracy may make it possible for more detailed labeling by processors. With such technologies, the chances for strategic behavior are improved as previously standardized commodities are transformed into customized intermediate products.

Existing information systems can also favorably affect the opportunities for coordination behavior that will result in a competitive advantage. Some components of information systems may have evolved for a different purpose but could eventually facilitate coordination. Systems to communicate with producers, such as Data Transmission Network or the FarmDayta system have been shown to be viable from both a technical and a market perspective (Reiff). Customer databases currently developed by American Express and other major credit card companies may eventually be linked to food products, creating potential for detailed market analysis, as well as opening the way for individualized service. Databases such as the one built by Del Monte to categorize and analyze consumer complaints might be a source of information that would have strategic implications beyond customer service.

Thus, market structure, production technology, and information technology condition the environment in which the agribusiness sector can evolve. However, the achievement of competitive advantage will depend most crucially on the attitude and vision of the participants. To exploit the potential strategic advantages made possible by information technology, players must recast their roles within the sector to respond to the consumer orientation in ways which will in-

crease profits. This is a challenging task, especially where low margins traditionally have fueled adversarial relations between various levels of the sector.

Implications for Agricultural Economists

The potential for using information technology to coordinate activities within the food and agribusiness sector presents challenges and opportunities for agricultural economists. The following discussion highlights several areas in which agricultural economists have opportunities to contribute through research and/or educational activities.

On a conceptual level, the framework used by researchers to portray the sector must continue to evolve, taking into consideration new coordination opportunities. Just as a broader vision is needed within the industry, we too must transcend our traditional view of sector levels and of the interplay between those levels. The conceptual framework presented in this paper suggests a variety of directions for empirical research.

For example, case studies could provide useful insight into factors that prevent or enhance the use of information technology in sector coordination. Applications of game theory may aid in understanding how the potential for coordination is affected when players have different amounts of market power or where information is asymmetric. The potential for information technology to either reduce or increase the differential in access to information should be considered in the context of market stability and viability.

Agricultural economists might also help analyze alternative contractual arrangements at the farm production level to see how information technology and coordination efforts impact the risk/return trade-off. Interestingly, if negotiated terms become more common in transactions between different levels within the sector, it may become inappropriate to rely on analysis of market prices relative to an idealized standard of perfect competition. As suggested by Doering, changing market conditions may necessitate a departure from the neoclassical approaches so routinely employed.

In a slightly different vein, agricultural economists might also play a role in helping to create and implement the expanded use of information technology in sector coordination. For example, analysis of scanner and other electronically acquired information may provide new insights on consumer behavior. Agricultural economists could also help design and/or evaluate food labeling innovations aimed at responding more accurately to emerging consumer concerns. At the farm level, work is needed to adapt information systems to import data from players in other sectors or to provide key data to merchandisers on newly desired product attributes. This is related to multidisciplinary efforts to develop an information system structure which is fully integrated internally and externally. The agricultural economist's historic capability to lead multidisciplinary initiatives could be a significant asset in such settings (Swanson). Another important contribution would be to help producers evaluate the costs and benefits associated with customizing output to meet end-user demands.

As technology makes it easier to combine and transfer data, questions will arise about trade-offs between private benefits and social welfare. More broadly, Tom Urban, chief executive officer of Pioneer Hi-Bred International, suggests that the impact of information technology must be assessed "for farm policy, rural structure, and worldwide competitiveness." Agricultural economists can help to analyze the costs and benefits of coordination strategies, considering not only industry participants but consumers as well.

Conclusion

We have argued that several trends are shaping competitiveness in the food and agribusiness sector as a result of information technology. Consumers are more aware of what they are consuming and as a result are demanding certain product attributes. Retailers are able to track tastes and preferences on product attributes with greater accuracy. Thus, players at other levels in the production and marketing continuum are pressed to respond not just to the next level in the chain but also to the ultimate consumers.

The changes in the production-marketing spectrum of the food and agribusiness sector have led to the blurring of traditional lines and to the addition of a value-added sector between the commodity processor and the wholesaler. At the same time, various technologies, such as networking, scanning, video interfaces, and control technologies, are emerging which greatly facilitate the sharing of information between business entities.

The convergence of these trends opens a stra-

tegic avenue for the food and agribusiness sector in identifying key opportunities where information technology can help coordinate efforts to respond more directly to the consumer. These opportunities will be most abundant where current market structure does not pose barriers, and where existing production and information technologies enhance the saving and sharing of information relevant to consumer demands.

The changes occurring in technology and in the structure of the food and agribusiness sector pose opportunities for industry players and for researchers. To exploit those opportunities will require vision. We hope this paper helps to broaden our view of the agribusiness sector and the role of information technology in carrying out coordination strategies which increase competitiveness.

References

Capps, Jr., O. "Utilizing Scanner Data to Estimate Retail Demand Functions for Meat Products." *Amer. J. Agr. Econ.* 71(1989):751–60.

Davis, G. B., and M. H. Olson. *Management Information Systems, Conceptual Foundations, Structure, and Development*. New York: McGraw-Hill Book Co., 1985.

Doering, O. "Looking Backward While Going Forward: An Essential for Policy Economists." *J. Agr. Econ. Res.* 43(1991):3–6.

Hudson, M. A. "Toward a Framework for Examining Agribusiness Competitiveness." *Agribus: An Int. J.* 6(1990):181–89.

Ives, B., and R. O. Mason. "Can Information Technology Revitalize Your Customer Service?" *Executive* 4(1990):52–69.

Kilmer, R. L. "Vertical Integration in Agricultural and Food Marketing." *Amer. J. Agr. Econ.* 68(1986):1155–60.

Konsynski, B. R., and E. W. McFarlan. "Information Partnerships—Shared Data, Shared Scale." *Harvard Bus. Rev.* 68(1990):114–20.

McMillan, E. "Changing Strategies to Meet Consumer Needs." Keynote address to the National Agri-Marketing Association convention, St. Louis MO, 23 April 1990.

McLaughlin, E., and W. Lesser. *Experimental Price Variability and Consumer Response; Tracking Potato Sales with Scanners*. Agr. Econ. Staff Pap. No. 86-28, Cornell University, Sep. 1986.

Mighell, R. L., and L. A. Jones. *Vertical Coordination in Agriculture*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. Agr. Econ. Rep. No. 19, 1963.

Packard, V. O. *The Hidden Persuaders*. New York: D. McKay Co., 1957.

Peters, T. "Prometheus Barely Unbound." *Executive* 4(1990):70–84.

Porter, M. E. *Competitive Advantage*. New York: Free Press, 1985.

Purcell, W. D. "An Approach to Research on Vertical Coordination: The Beef Industry in Oklahoma." *Amer. J. Agr. Econ.* 55(1973):65–68.

Rapp, S., and T. Collins. *The Great Marketing Turnaround*. Englewood Cliffs NJ: Prentice-Hall, 1990.

Reiff, R. "Keep It Simple." *Forbes* 144(1989):226–27.

Shannon, C., and W. Weaver. *The Mathematical Theory of Communication*. Champaign-Urbana IL: University of Illinois Press, 1949.

Shrader, L. F. "Responses to Forces Shaping Agricultural Marketing: Contracting." *Amer. J. Agr. Econ.* 68(1986):1161–66.

Shaffer, J. D. "Food System Organization and Performance: Toward a Conceptual Framework." *Amer. J. Agr. Econ.* 62(1980):310–18.

Sonka, S. T., and M. A. Hudson. "Why Agribusiness Anyway?" *Agribus.: An Int. J.* 5(1989):305–14.

Strassmann, P. A. *The Business Value of Computers*. New Canaan CT: Information Economics Press, 1990.

Streeter, D. H., and M. A. Hudson. "Information Partnerships in the Food and Agribusiness Sector: an Alternative Coordination Strategy." *J. Food Distrib. Res.*, in press.

Swanson, E. R. "Working with Other Disciplines." *Amer. J. Agr. Econ.* 61(1979):849–59.

Urban, T. N. "Agricultural Industrialization: A Think Piece." Speech presented to the Food and Agriculture Committee of the National Planning Association Washington DC, 21 Sep. 1990.

Agribusiness Competitiveness in the 1990s: Discussion

Michael L. Cook and Maury E. Bredahl

Streeter, Sonka, and Hudson (SSH) are to be congratulated on their willingness to address the relationship between information technology, coordination, and competitiveness. Throughout the paper there are nuggets that could be polished and brought to market. Yet, the implicit objective of developing a conceptual framework is still missing. And SSH struggle to enhance the economist's and the agribusiness manager's ability to link a factor (computerized information technology), a process (coordination), with a yet-to-be-well-defined phenomenon (competitiveness).

As the authors continue their work in this area, it would be beneficial to start with a theoretical framework derived from organization theory or the economics of organizations which query into issues, such as "Does a given technology encourage the move from markets to hierarchies or vice versa?" or "The degree of coordination is affected by which types of technologies, demand forces, or supply shifters?" SSH insightfully acknowledge the complexity of this second issue by expanding on the breadth of consumer demanded attributes in the agribusiness sector. Furthermore, they identify examples which contribute to our understanding of the increasingly multifaceted objective function of the "new" food consumer.

The challenge to conceptualize more rigorously, develop detailed case studies, reconceptualize, and finally develop empirical work remains ahead of us before economists can contribute to the individual firm's strategic planning process or the public policy field in this area. SSH have made a contribution to this effort by identifying numerous interrelated factors and a challenge of a well-thought-out research agenda.

The Martin, Westgren, and van Duren (MWD) paper deserves an acknowledgement, a compliment, and an admonishment: (*a*) Acknowledgement: Canada, as a nation, is addressing the difficult question of its "competitiveness" in the North American market for food and agricultural products. (*b*) Compliment: MWD are to be complimented for exploring new conceptual and empirical areas. Moreover, it is an area where testable hypotheses are often presented as facts. (*c*) Admonishment: Competitiveness can be viewed in many different ways. The [ ] in the following questions can be completed with a random choice of geographic area (space), product (form), or time: (*i*) Is [firm, for example] competitive in the [poultry, for example] market? (*ii*) Is the [geographic area] poultry sector competitive in the [geographic area] animal protein market? (*iii*) Is the [ ] poultry sector competitive in [December]? These alternative views of competitiveness must be reflected, if possible, in a definition of competitiveness.

Modifying the definition offered by Sharples and Milham, being competitive is the ability to deliver goods and services at the time, place, and form sought by buyers, in both the domestic and international markets, at prices as good or better than those of other potential suppliers, while earning at least opportunity costs on resources employed. This definition suggests three levels of competition: (*a*) international markets, (*b*) the domestic market for products, and (*c*) the domestic market for resources. The definition admits the possibility that firms (sectors) can influence the price received for outputs. Analytically, economic concepts derived from the theory of comparative advantage, such as the law of one price, should be treated as testable hypotheses.

MWD chose to define competitiveness in terms of the outcome of the definition offered above: "the sustained ability to profitably gain and maintain market share." This definition leads to comparisons of profitability, as measured at the sector level by value added, and market shares in North American markets.

The use of value added as a measure of sustained profitability, measured per worker or per dollar of shipments, is one way of ascertaining the ability of firms (sectors) to influence price as well as cost. The concept of value added uti-

Michael L. Cook and Maury E. Bredahl are professors in the Department of Agricultural Economics, University of Missouri.

lized by MWD is different than that normally used in the United States.

Value added in the United States is most often associated with increased processing: "There is increasing concern, however, that America is not utilizing its full *competitive advantage* from its production of agricultural products. If markets for processed agricultural products exist abroad, why does the United States not capture more of the potential jobs and related economic activity than domestic processing offers" (Schluter and Edmonson, p. 1). The policy proposal is the shifting of export subsidies from raw commodities to processed products.

Value added as used in this paper, and as promoted by Porter and others, is a much broader concept: "Firm's gain competitive advantage from conceiving of new ways to conduct activities, employing new procedures, new technologies, or different inputs" (Porter, p. 20). In this sense, increased value added may be achieved either by reducing costs (of all kinds) and/or product differentiation. The policy proposal is to increase the level of education and training of the work force and the efficiency and breadth of supporting infrastructure.

In addition, the actual calculation of value added means different things to different people. The following are alternative definitions: Value added for an industry is calculated by subtracting the cost of purchased inputs from the value of shipments and value added is the sum of payments to all factors of production utilized in the industry. A session at this meeting explored alternative calculations of farm-level value added, and so exposed the lack of commonly accepted method of calculation.

Beyond the definition of and method of calculating value added is the meaning of cross-country or cross-industry comparisons. A similar evaluation holds for market share data. Sustained market share captures the effect of competitive factors but it explains little.

The analysis of this paper serves to point agricultural economists toward a literature, and analytical techniques, that could augment and extend our analysis. In this paper, (*a*) the analysis of the poultry sector should be augmented with an analysis of product mix and differentiation, (*b*) the red meat analysis is too aggregated to be meaningful, and (*c*) too much emphasis is placed on economics of scope and scale as explanations for observations. With that said, the paper surfaces an excellent set of testable hypotheses in line with the emerging literature on competitive (the other "c" word) advantage.

References

Porter, Michael. *The Competitive Advantage of Nations*. New York: Free Press, 1990.

Schluter, Gerald, and William Edmonson. *Exporting Processed Instead of Raw Agricultural Products*. Washington DC: U.S. Department of Agriculture, Economic Research Service, Nov. 1989.

Sharples, Jerry, and Nick Milham. *Long-run Competitiveness of Australian Agriculture*. Washington DC: U.S. Department of Agriculture, Economic Research Service For. Agr. Econ. Rep. No. 243, Dec. 1990.

Agribusiness Competitiveness in the 1990s: Discussion

Dean A. Mefford

Without question there is a need for increased coordination within the agribusiness sector in today's environment. The argument by Streeter, Hudson and Sonka that an increasing consumer-oriented business environment has enhanced and hastened coordination strategies between various levels of the sector is absolutely correct, in my opinion.

The problem is that not all levels of the sector have come to realize how correct that argument is for their own survival. The movement to highly integrated poultry, hog, and cattle operations has come in large part because producers could not get the coordination and cooperation they needed with all the subsectors from the seed company to the feed products, to the machinery suppliers for specific processing, to the processors. The solution: I will control as much of the process as possible by myself so that I can assure it will be done my way. We see the evolution in the form of the Tysons and ConAgra's of the world. Even they cannot control the final link, which is the grocery chains, but the power they have gained by branding and processing makes them important to the successful supermarket chain.

The problem today is that the technology to do great things is there; however, it is not being exploited at all levels of the sector because of little or no coordination. For example, we know that high lysine corn can have a positive impact on swine production, especially if it is fed to swine with a specific genetic make-up to utilize the higher lysine levels. Seed companies can provide the seed, farmers can grow the corn, feed producers can use the grain to produce the feed, pig breeding companies can produce the pigs, and farmers can buy the pigs and the feed. However, someone must assemble this information and influence all these sectors about advantages to each level to doing the necesary activities. The easy way is for a Cargill or a Tyson to integrate the process totally.

In my opinion, one of the major problems in animal agriculture is that we have paid little attention to consumer wants and desires in the past; rather, costs and production efficiencies have received too much emphasis. As a result we produce poultry that is too fat and tastes like cardboard. We produce, or have in the past, with too much fat because of the focus on cost per pound of gain and conversion instead of focusing on carcass quality and taste of the end product. We have not worked with the food processors to focus on attributes they were looking for in the milk, meat, and eggs they use. In many cases they have created impressive, but costly, processing systems to remove fat and cholesterol that could have been more efficiently and effectively left off at the farm with the right genetic make-up of the animal and the proper feeding program.

Our marketing and collection system exacerbates the problem because in many cases it combines animals, milk, and eggs with no quality differentiation and pays little premium to the best producers over the poor producers. A clear example today of waste is the dairy area, and it is not helped by governments around the world. With the whole world scrambling to reduce fat in the diet, what do we insist on in raw milk and penalize if it is not there—fat. If milk is not at least 3.5% fat, we penalize the producer. Of course, the milk processor spends a lot of money and time extracting the fat so he can sell .5% or skimmed milk. But you say the fat is needed for butter; of course, that ignores the fact that the world if full of butter and milk fats called casein. It costs more to produce the higher fat levels in milk and reduces the output per cow, and it costs more to process the milk. Why do we have the rules and system we do? No coordination and failure to see the forest for the trees.

We need computer-based systems and communications capabilities to provide all the sectors with information needed to allow the necessary coordination. If a meat processor needs a certain type of carcass produced at a reasonable level of cost, producers need to have ready

---

Dean A. Mefford is Corporate Vice President and President of Ralston Purina International.

access to that information and, in turn, pig breeders and feed suppliers also need that information. Today they all fight the system because no one knows what the others are trying to achieve. The producer may have a bacon-type pig that he attempts to grow to produce hams for the processor. The feed person attempts to adapt his feeding program and the processor takes a pig he does not want and discounts the price to the producer. With better information and coordination, everyone could have done a better job and produced a premium product.

The French have made the best progress in this area, although many improvements still can occur. We should develop their information system or perhaps hire them to install it. It provides considerable information to all members of society, especially in the agri sector, in addition to providing capabilities for all the sectors to communicate and retrieve valuable data base information.

There is no question that information partnerships can provide strategic advantage for market players. As the retail trade and the food industry consolidates, the business person with an information advantage has competitive advantage. Those who can tie in their information systems with the different players can lower costs through the entire system.

In my opinion, better information systems can allow us to return to the medium to small size producer who can be a major player in the consumer-oriented agribusiness sector. They can be flexible enough to produce against the specifications of the next level and receive a premium for that production.

The entire system needs to adapt to today's reality. We live in a new time, and capabilities in information technology allow us to abandon the old inefficient way of mass producing against efficiency and cost standards instead of producing to consumers' wants and desires.

I cannot comment on all aspects of the paper by Martin, Westgren, and Van Duren because I am not knowledgeable on all the sectors discussed. However, our company is a participant in the animal feed sector in Canada and a former participant in poultry production, so we do understand the problem.

I believe the key issue is the protection that has been afforded producers in almost all agricultural sectors in Canada over the past several years. While marketing boards seem to protect producers, they essentially have rewarded inefficiency and discouraged investment in better productivity. For poultry, the marketing boards have controlled quantity of production and set prices based on their own projections and past cost experiences. When you can indiscriminately pass on your cost increases, there is little incentive to work at increasing productivity and lowering the cost of production. I know of broiler operations that were so poorly managed that, even with death losses of 15% or higher, they could achieve profits of $1 per bird.

In contrast, the swine industry in Canada has no marketing board and has not been protected by cartel pricing practices. They are very competitive in serving the U.S. market, to the extent that they have seen retaliation from the U.S. side of the border. Here is an industry that has had to fight for productivity in order to remain competitive, and they are very viable under the free trade agreement.

In Quebec we have seen a consolidation of farming, processing, and marketing by the government-supported co-op. They have purchased farms, quota, and have made large capital investments in processing facilities. As quota is eliminated with the marketing board, it will be interesting to see if the Quebec government will stand behind the huge losses that will surely come to this co-op. This program of collectivization is second only to Russia, with the exception that they used taxpayers' money to buy up farms and quota. The champion of the individual entrepreneurial farmer, the co-op, has effectively eliminated the people they supposedly represent and yet has not increased the productivity or reduced the cost of the end product production.

Limited Resource Farmers: The Impacts of Farm Policy

Leroy Davis

The main goals of this invited paper session are to assess the historical efforts of the agricultural economics profession to address the problems of limited resource farmers and to offer some suggestions and/or strategies for redress of the current problems confronting limited resource farmers. The main objectives of this paper are to focus on the policy issues, policy formation, and ultimate impacts on limited resource farms and structural adjustments.

Because agricultural policy formation and its implementation are complex, multifaceted, and involve many entities, no attempt will be made to delineate all aspects of this process. The paper will address some of the issues, the causes, and to some extent, the impact of agricultural policy formation and its implementations *vis-à-vis* the limited resource farmers and the agricultural economics profession.

Role of Agricultural Economics

The topic, limited resource farmers, implies that a group of farmers is not endowed with adequate productive factors, skills, and organizational support to move into the mainstream of economic activity in the farm sector. Hence, some form of welfare or income transfer policies would be needed to bridge the gap between those who are well endowed (mainstream farmers) relative to those who are less well endowed (limited resource farmers). If this in fact were a goal of farm policy, then what profession or group of professions would be responsible for addressing this issue? Because of the behavioral nature of agricultural economics, a good case could be made that it should have that responsibility. Some would argue that the responsibilities of dealing with human issues or nonmarket adjustments would fall on the rural sociology profession.

The question becomes, why not agricultural economics as the profession that would address the differences in resource endowments among producers? The answers may be embodied in the organization and structure of the profession and the main body of economic theory that is utilized by agricultural economists.

Most agricultural economists are trained at and employed by large land grant universities whose main mission is to serve the agribusiness sector of the state and the nation. Food and fiber production and marketing are big businesses. The resources of these departments are allocated along commodity lines. That is, the major cash-producing enterprises have received most of the resource allocation. This is a logical way to proceed, given the role, scope, and mission of the land grant institutions. Production economics followed by marketing has traditionally received most of the departmental resources. Individuals in the profession are trying to succeed as economists, trying to earn good incomes, and possibly to become famous. These are worthy goals for personal success. However, such a system does not readily lend itself to addressing problems of limited resource farmers and differentials in income among producers.

Neoclassical economic analysis, which is taught, fostered, and applied in these land grant institutions, does not focus upon resource differences and income differentials among producers. Many of these conditions are assumed not to exist. The market is the mechanism for efficient allocation of factors of production and products. Efficiency and growth are essential conditions for the neoclassical model to work successfully. Given the limited resource base, especially land, the farm firm must grow in size to be efficient, to prosper, and to survive. In this situation some firms will not survive, and those

Leroy Davis is a professor, Department of Agricultural Economics and Agribusiness, Southern University and A&M College.

that are not growing will receive little attention or will be totally ignored. This is a dynamic system where markets and economic conditions will mitigate against limited resource farms.

Policy Formation Process

Farm policy formation is a complex and dynamic process. For the most part, limited resource farmers have not participated as an entity in agricultural policy formation. In recent years consumers and environmentalists have been participants, yet the limited resource farmers as individuals and as members of other groups have little or no input in farm policy making.

Traditionally, policy makers have been influenced by commodity groups, agribusiness firms, and others in the commercial agricultural sector. In the 1960s, during the civil rights movement, some effort was made to have limited resource farmers represented in the agricultural policy formation system. A number of "emerging cooperatives" were organized with the support of the U.S. Department of Agriculture. Some limited funding was provided for this effort. Some regional technical and financial assistance groups were also organized with the support of some large private foundations, such as the Ford Foundation and the Rockefeller Foundation. In the early years of these organizations, a limited amount of success was realized. Those groups represented small or limited resource farmers in the southern and border states. However, their impact on agricultural policy formation was minimal and short lived.

Further decline in the number of limited resource farmers was experienced over the past two decades. This decline, coupled with the growth in the commercial farm groups and the emergence of other interest groups, has lessened the influence and potential impact of limited resource farmers in farm policy formation.

The 1990 Farm Bill

For a number of years, the agriculture sector has been considered to have excess capacity, especially human resources and land resources. That perception has remained to this day. The 1990 farm act and the 1990 Budget Reconciliation Act have as their main policy goals: (*a*) to reduce the federal deficit, (*b*) to improve agricultural competitiveness, and (*c*) to enhance the environment. The main aims here are to reduce the program costs by limiting subsidies, to have a more market-oriented policy, and to reduce the negative impact on the environment (U.S. Department of Agriculture).

Although some slight changes have occurred in immediate goals, the long-run goal of a cheap food supply has not been changed for some years. The principal structure of U.S. agriculture has also not been altered. That policy has been commodity based and land based.

Limited resource farmers tend to produce a variety of enterprises to take advantage of limited land resources and to exploit the relative availability of human resources. Many of the specialty crops and livestock produced by these farmers are not included in the U.S. farm policy. Thus, there are no income or price protection policies for those enterprises. In some cases, limited resource farmers will produce the major enterprise for the region in order to benefit from existing farm policies; however, their relatively small operational size leaves them at a decided disadvantage.

The present policy is land based, as have been the previous policies. That is, farmers are compensated based on the amount of land taken out of production or the historical level of production. This practice has enhanced farmers who are land resource-endowed and has hurt the farmers who are land resource-poor. Such policies have led to enhanced absentee farming and speculation in land values. It has worked toward the advancement of large farms and against the survival of small and limited resource farms. It is clear the structure of agricultural policy has been oriented toward farm production efficiency by increasing the size of operation, reducing the relative labor input, and enhancing the movement toward growth in farm size.

The Role of 1890 Universities

There are seventeen 1890 land grant universities in sixteen southern and border states. These institutions have traditionally served the limited resource farmer and, to a large extent, black farmers in those states. Since their inception, the 1890 universities have been resource-poor, and their mission has been effectively limited to providing teachers for high school vocational agricultural and home economics programs and

extension workers who served that same clientele. From 1920 until about 1970, agricultural economics programs in 1890 institutions were manned by, in most cases, one person who taught most of the courses to vocational agricultural students. There were neither enough human nor physical resources to conduct research or provide extension services to the limited resource farmers (Davis).

In the early 1970s, the USDA provided some small grants to initiate research projects at those institutions. In the 1970s, 1890 extension programs were also started but with close ties to the 1862 extension programs in those same states. During the mid-1970s to the early 1980s increases in funding for those programs were sustained. However, in recent years the money value of those programs has been static and the real value of the funding level, when adjusted for inflation, has declined.

Some growth in demand for agricultural economists at the 1890 institutions occurred during the 1970s and early 1980s. To date, five programs are functioning as departments, with faculty members ranging from two to five. By 1980, nine of the seventeen institutions had agricultural economics departments with faculty members producing research publications for professional journals at the regional and national levels (Beilock, Polopolus, and Correal). Two of the nine departments were producing enough publications and research reports to receive some recognition from professional agricultural economists at major institutions and in the U.S. Department of Agriculture (USDA). Even with this growth and recognition, faculties remained very small, teaching loads relatively heavy, and progams at the undergraduate level. The absence of graduate programs and the lack of a critical mass of graduate students hampered the success of these programs and their ability to address the issues facing limited resource farmers. The lack of financial support at the state level was another major hindrance to the 1890 institutions and their mission of addressing the needs of limited resource farmers. The issue of state funding for 1890 research programs will remain critical for some time into the foreseeable future.

Some 1862 institutions and some non-land grant institutions did publish some papers in the 1970s and 1980s on limited resource farm problems. However, the resource allocation to this issue was limited and not sustained. Only traditional programs that are a part of their main mission have continued to be studied at sustained levels.

Some Strategies and Suggestions

It is clear that the mission and structure of the 1862 land grant institutions do not lend themselves to the support of the issues facing the limited resource farmers. Further, it is shown that agricultural policy formation and its composition do not support the plight of limited resource farmers. Even though the 1890 universities have embraced the mission of serving those farmers who are resource-poor, these institutions are themselves resource-poor and are quite limited in addressing the problems confronting the limited resource farmers. Hence, some other strategies must be employed if the problems of the limited resource farmers are going to come to the attention of agricultural economics and other professions.

The limited resource farmers must become involved in the policy formation and implementation process, just as the environmentalists and consumer groups have done. This can be done by organizing and developing support groups. Leadership must evolve from the farmers themselves; it will not be provided by persons in the professions, such as agricultural economics. The professions are not structured or endowed with the resources or independence to be of real service to limited resource farmers.

However, persons in professions such as agricultural economics can play an important role. Before the professionals can be effective, a paradigm shift must occur. The paradigm reflects the traditional models for professional growth and development and the neoclassical growth and efficiency models that are utilized in agricultural economics. Some new forms of incentives for professionals in the land grant complex must be developed and implemented, and some new economic models must be developed that do not depend heavily on growth as the essential criterion for success. To develop such a system will be a real challenge to this profession and others in the food and fiber production system.

Perhaps coalitions can be built between 1890 and 1862 institutions. These proposed coalitions could provide complementarities for both the 1890 and the 1862 institutions because the 1890 institutions have embraced the mission of working with limited resource farmers and the 1862 institutions have the mature resource base. For such an arrangement to be successful, much forethought and planning will be required. The 1862 institutions must also support the efforts of the 1890 institutions to acquire resources from their state governments. Some programs at the

federal level have been successful in combining the efforts of diverse institutions to attain specific goals.

References

Beilock, Richard P., Leo C. Polopolus, and Mario Correal. "Ranking of Agricultural Economics Departments by Citations." *Amer. J. Agr. Econ.* 68(1986):596–604.

Davis, Leroy. "Resident Instruction Programs at 1890 Institutions." *A Century of Service: The 1890 Land Grant Colleges and Universities*, pp. 47–51. Rutgers NJ: Transaction Publishers, forthcoming.

U.S. Department of Agriculture. "A USDA Staff Briefing—The 1990 Farm Act and the 1990 Budget Reconciliation Act." Washington DC, Nov. 1990.

Limited Resource Farmers' Productivity: Some Evidence from Georgia

Mack C. Nelson, Nathaniel B. Brown, Jr., and Letitia F. Toomer

The structure of American agriculture has been characterized historically by large numbers of relatively small, family-operated farms. During the past forty years or so, however, the number of farms in the United States has declined by more than 50%. The reduction in farm numbers has been more pronounced in the noncommercial and small commercial farm classes during this period. The decline is drastic even after considering the changes in the definition of a farm used by the Bureau of the Census and the Department of Agriculture. Large farms have shown an almost steady increase in numbers during this period (Carr). Even with the drastic decline in the number of small farms, they still account for a large proportion of the nation's total farms. According to the 1982 Census of Agriculture, about 76% of the nation's farms are small. The South, one of the regions with the largest number of small farms, has in excess of one million farms, and over 80% of these farms are defined as small. Georgia has approximately 49,627 farms; at least 67% of its total are small farms (Brown).

Limited resource farmer (LRF) is a term used to describe the traditional small, part-time farmer throughout the United States. The term limited resource farmer apparently took its origin from the financial assistance program developed by the Farm Home Administration and approved by Congress in 1978 via the Agricultural Credit Act. However, the concept of limited resource farmer pertains to the lack of adequate inputs for the normal operation of the farm business. Additionally, the term limited resource farmer is sometimes used interchangeably with low-equity farm, low-income farmer, small-scale farmer, marginal farm, and small farm (Carlin and Crecink, Chidebelu, Tweeten).

Previous studies by Saupe, Chidebelu, Tweeten (1982), Faust, Beauford, Williams, and Yeboah and Strickland address production, financing, and structure of agricultural issues applicable to the small farm issue. Recently, more concern has been directed to the survival issues of the limited resource farmer, especially as it relates to structural changes that are occurring. Beauford alluded to the fact that a major difference exists between the income-generating strategies, patterns of household income, racial make-up, and geographic location of small farms compared to that of larger farmers. She concluded that, while differences exist between farm-income-dependent and nonfarm-income-dependent households, their economic well-being remains relatively the same.

Limited resource farmers have been, and continue to be, important in terms of their numbers and the resources that they control. There are indications that beliefs about small farms could adversely affect their accessibility to needed resources and services. These include the notion that limited resource farmers are inherently inefficient, resulting in less-than-optimal use of resources (Crecink, Houston, Atkinson). Some studies seem to show, however, that LRFs are not inefficient in the allocation of resources. For example, Singh and Williamson found that part-time farmers were no less efficient in the allocation of resources than full-time farmers. Bagi reported that technical efficiency differences for small and large crop farms were virtually nonexistent. The mean output values for the samples in both studies for small and large farms were about $10,000 and $33,000, respectively. This suggests that the large share of both classifications was on the lower end of the spectrum

Mack C. Nelson and Nathaniel B. Brown, Jr., are professors of agricultural economics and resources economics, respectively, at the Agricultural Research Station, School of Agriculture, Home Economics, and Allied Programs, Fort Valley State College, Georgia; Letitia F. Toomer is an agricultural economist with the Soil Conservation Service, U.S. Department of Agriculture, at Chickasha, Oklahoma.

and may not be representative of the groups. Further, because of the continuing controversy surrounding the use of resources on these farms, it seems appropriate to examine their use and allocation on small farms relative to large farms. Hence, the objective of this study was to examine the physical economies of scale (technical) and allocative efficiency between limited resource and commercial farms.

A review of the literature suggests that there is no commonly accepted definition of a small or limited resource farm (Nelson et al., Brown). Common definition parameters range from acres of land to value of farm products sold. Carlin and Crecink suggest that two fundamental concepts appear to be the basis of the most frequently used definitions of a small, or limited resource, farm. The first one emphasizes a low volume of business, whereas the second considers a farm operator-family having a low level of economic well-being. Small or limited resource farms in this study are defined as those farms with gross annual sales of at least $2,500 and equal to or less than $40,000. Commercial farms are defined to include all farms with gross sales in excess of $40,000.

Data and Description of Selected Characteristics

In 1982, a survey of farms with gross sales of $2,500 or more was conducted. The data presented and analyzed in this paper are from two contiguous South Georgia counties included in the survey. The data presented on farm families from the two-county area were obtained by random selection from lists of names of farmers prepared and cross checked by agricultural agency personnel of the two counties. Trained enumerators from each county were used to collect the information. A total of 116 usable schedules were collected from the two-county area; they represent 12.4% of the farms in the area with gross farm sales of $2,500 and more.

The sample makeup is 70.6% limited resource farms and 29.3% commercial farms (table 1). The sample also consists of approximately 11.5% of the large farms and 12.8% of the small farms in the study area. The sample also represents about 38% of the black-owned farms in the study area with gross sales of $2,500 or more.

Table 1. Selected Characteristics of Sample

Item	Commercial Farmers	Limited Resource Farmers	Sample Total
≤$40,000 (%)		70.7	
>$40,000 (%)	29.3		
Renter (%)	70.6	26.8	39.7
Renter of tobacco (%)	35.3	18.3	23.3
Renter of peanuts (%)	29.4	02.4	10.4
Produce tobacco (%)	52.9	36.6	41.4
Produce peanuts (%)	41.2	19.5	25.9
Produce vegetables (%)	29.4	23.2	25.0
Black (%)	32.4	46.3	42.4
≥65 Years (Black) (%)	8.8	18.3	15.5
≥65 Years (%)	20.6	35.4	31.0
Average age (years)	48.03	57.3	54.6
Completed high school (%)	47.1	24.4	31.0
College—2 years (%)	14.7	09.8	11.2
Ave. acres owned (no.)	211.38	100.63	133.1
Ave. acres operated (no.)	379.40	71.28	161.6
Range, acres owned (no.)	0–1,175	0–501	0–1,175
Range, acres operated (no.)	25–1,355	5–200	5–1,353
Operators reporting off-farm work (%)	38.2	41.5	40.5
Spouse reporting off-farm work (%)	26.5	39.0	27.6
Labor/farm (hours)	3,603	1,367	2,022.38
Labor/acre (hours)	9.50	19.18	12.52
Reporting hired labor (%)	82.40	61.00	67.3
Fertilizer and chemicals/farm ($)	23,005.21	3,789.34	9,421.6
Fertilizer and chemicals/acre ($)	60.64	44.74	55.6
Output/farm ($)	111,772.15	16,885.87	44,697.37
Output/acre ($)	294.60	236.90	276.61

Model Specification

The components of economic efficiency of farms can be estimated using the production function approach. However, Singh and Williamson point out that, when one uses this approach, the linearity and homogeneity assumptions should be tested because of the sensitivity of the technical component to the specification of the model. The linearity assumption is satisfied if the returns-to-scale coefficient equals one. Accordingly, these assumptions were tested for the production function describing the sample, and the efficiency measures were estimated. A Cobb-Douglas production function in log-linear form was fitted to the observations using ordinary least squares. The dummy variable approach suggested by Gujarati and Maddala is employed rather than the traditional method of fitting separate models and testing for the equality of coefficients between models. The model was estimated and the coefficients tested. A second model was estimated using all inputs and dummy variables that were statistically significant. The Cobb-Douglas function that was fitted is as follows:

$$
\begin{aligned}
Y = {} & LnI + LnD + B1\,LnL + B2\,LnLD \\
& + B3\,LnF + B4\,LnFD + B5\,LnLS \\
& + B6\,LnLSD + B7\,LnA + B8\,LnAD \\
& + B9\,LnM + B10\,LnMD + B11\,LnO \\
& + B12\,LnOD + Ei,
\end{aligned}
$$

where Y is dollar value of all farm production. It includes the value of all crops, crop by-products, livestock and livestock products, change in inventory, and market value of home-consumed products.

L is number of hours of labor actually used on the farm. It includes the operator's labor, family, and hired labor. An adjustment factor equal to .6 was used for all operators equal to or greater than 65 years old, and a factor of .7 was used for family labor supplied by the spouse less than 65 and dependent children less than 18 years old.

F is dollar value of fertilizer, pesticides, herbicides, lime, and other chemicals.

LS is dollar value of all feed, health care, and all other miscellaneous expenses associated with livestock.

A is number of acres operated per farm, including acres rented from others and pasture.

M is annualized estimates of services from machinery and equipment (including trucks and irrigation) plus expenditures on fuels-oils, custom hire, and contract work of machinery and equipment services. This variable also includes the annualized value of selected reality items.

O is all other expenses that are not directly related to those listed above. For example, general utilities, seeds, bulbs, plants, and trees.

Results and Discussion

The results of the production function analysis are presented in table 2. The results show that the elasticity of production for land and machinery are significantly different for LRFs and commercial farms. The remaining variables—labor, fertilizer, livestock and other expenses—coefficients are not significantly different for the farms. These differences suggest that the LRFs and commercial farms groups are represented by different production functions.

Next, a comparison of the allocative efficiency of resource use between farm size was examined. To test for allocative differences between the farms, the assumptions of constant returns to scale, the existence of a competitive in-

Table 2. Elasticity of Production Estimates of Cobb-Douglas Production Function for LRF and CF

Variable[a]	Estimates
Intercept[b]	2.8659
	(.4066)
Labor	.1501
	(.0963)
Fertilizer	.0859
	(.0868)
Livestock	.0556
	(.0583)
Acres	.5094
	(.1387)
Machinery	−.1257
	(.1168)
Other expenses	.2547
	(.0874)
D*Acres	−.4894
	(.2414)
D*Machinery	.6326
	(.2412)
Dummy*Intercept	−2.083
	(.8498)
R	.8095
F	32.37
DW	1.8591

[a] Figures in parentheses are standard errors of the estimates.
[b] Limited resource farm elasticity of production estimates are given by the variable estimates; variable estimates for commercial farms are given by the addition of the limited resource estimates and the D^* variable(s) estimates.

Table 3. Elasticity of Production, Average Product, Marginal Product, and Allocative Efficiency Estimates for Limited Resource Farms and Commercial Farms

Item	Ep	AP	MP	Allocative Efficiency
Commercial Farms				
Labor (hours)[a]	.1501	31.02	4.66	1.39
Fertilizer ($)	.0859	4.86	.418	.418
Livestock ($)	.0556	30.66	1.71	1.71
Acres[b]	.0200	294.60	5.89	.10
Machinery ($)	.5069	8.61	4.36	4.36
Other ($)	.2547	4.44	1.33	1.13
Limited Resource Farms				
Labor (hours)	.1501	12.35	1.85	.55
Fertilizer ($)	.0859	4.46	.383	.383
Livestock ($)	.0556	8.81	.49	.49
Acres	.5094	236.90	120.68	2.01
Machinery ($)	−.1257	4.93	−.62	−.62
Other ($)	.2547	4.09	1.04	1.04

[a] Most farms reporting hired labor and wage rates averaged about $2.50 per hour; an adjustment for skilled labor was made to $3.35 per hour.
[b] The average annual land rental charge in the area varied from $40–$50 per acre for bonafide rental. A rental charge of $60.00 was used to account for the rental of tobacco and peanut production privileges.

put-output environment and neutral technology should be satisfied. Table 3 shows that these farms' enterprise selection is fairly homogenous, and the sizes of the farms are sufficiently large to capture product price premiums and input discounts, if they exist. Also, the sample was drawn from two contiguous counties. The cumulative elasticity of production for the LRFs is slightly less than one and slightly greater than one for the commercial farms, but these results are not significantly different.

Assuming the aforementioned conditions are satisfied, the allocative efficiency measure is $A_E = MVPxj/Pxj$, where MVP is the marginal value product of the j's input and Pxj is the cost per unit of the j's input. A_E equals one for optimum input use. When A_E is less than one, the resource is overutilized; when A_E is greater than one, it indicates less-than-optimum resource use. The allocative efficiency coefficients show that LRFs use labor, fertilizer, livestock expenses, machinery, and other expenses more extensively than do commercial farmers. The negative coefficient for machinery on LRFs may indicate that the size of machinery complements owned is not warranted when viewed in terms of the number of acres operated. Put differently, it may indicate too much machinery for the small acreage operated. Similarly, the small, but positive coefficient for land on commercial farms may be the result of overexpansion in terms of land by these farms when price–income conditions were favorable.

Concluding Comments

In this paper we have briefly surveyed two different bodies of literature on resource use relationships between limited resource and commercial farms and found some degree of diversity. The most recent work seems to suggest that both types of farms are fairly efficient in the use of resources, but that there are efficiency differences between limited resource and commercial farms. The results of this study also tend to support this view. In this study it was found that the limited resource and commercial farms in the sample were represented by different production functions. Additionally, the results suggest that the land and machinery variables show significant differences in use for limited resource and commercial farms.

References

Atkinson, Ron. "Can Small Farmers Be Helped to Change? Yes or No?" S. Rural Develop. Ctr., *Rural Develop. Res. and Educ.* no. 4 (1977), p. 5.

Bagi, F. S. "Relationship between Farm Size and Technical Efficiency in West Tennessee Agriculture." *S. J. Agr. Econ.* 14(1982):139–44.

Beauford, E. Y. "The Effects of Alternate Income Strategies of Small Farm Households." Ph.D. thesis, University of Georgia, 1983.

Brown, N. B. *Marketing Activity of Limited Resource Farmers in Georgia through the Use of Cooperatives.*

University of Georgia College of Agriculture, T.833 (1989):110.

Carlin, T. A., and J. Crecink. "Small Farm Definition and Public Policy." *Amer. J. Agr. Econ.* 61(1982): 933–39.

Carr, B. A. "A Profile of the Commercial Agricultural Sector—A Historical Perspective on Changes in the Number and Size of Farms." Report to Committee on Agriculture, Nutrition, and Forestry, United States Senate, April 1980, pp. 24–25.

Chidebelu, A. S. N. D. "An Analysis of Factors Affecting the Commercialization of Limited Income Farms in Georgia." Dep. Agr. Econ. LXC 16, University of Georgia, 1980.

Faust, M. "New Methods, Worldwide, for Fruit Production on Small Farms." Washington DC: U.S. Department of Agriculture, Agr. Mktg. Serv. Misc. Pub. No. 1411, 1982.

Gujarati, D. "Use of Dummy Variables in Testing for Equality between Sets of Coefficients in Two Linear Regressions: A Note." *Amer. Statist.* (1970):50–52.

Houston, D. J. "Attitudes of Agricultural Agency Personnel and Low-Income Farmers Toward Each Other." *Arkansas Farm Res.* 28. May–June (1979).

Maddala, G. S. *Introduction to Econometrics*. New York: Macmillan Co., 1988.

Nelson, M. C., et al. "RR-2 Project Outline—Factors Influencing the Survival of Small Farms in the South." Fort Valley State College ARS, 1980.

Saupe, W. "Information Needs Relating to Small-Farm Programs and Policies." Washington DC: U.S. Department of Agriculture, ESCS Staff Rep., 1980.

Singh, S. P., and H. Williamson. "Part-Time Farming: Productivity and Some Implications of Off-Farm Work by Farmers." *S. J. Agr. Econ.* no. 2 (1981), pp. 61–67.

Tweeten, L. "The Economics of Small Farms." *Science* 219 (1983), pp. 1031–41.

U.S. Department of Commerce, Bureau of Census. *Census of Agriculture* 1978 and 1982, Washington DC, 1978, 1982.

Williams, T. T. "Strategies For Survival of Small Farms—International Implications." Tuskegee University, 1985.

Yeboah, A. O., and Sedalia A. Strickland. "Economic Condition of Limited Resource Farmers in North Carolina." Agr. Res. Bull. T-134, North Carolina A&T State University, June 1986.

Limited Resource Farmers and the Marketing System

Magid A. Dagher, Ralph D. Christy, and Patricia E. McLean-Meyinsse

In an attempt to improve the economic conditions of limited-resource farmers (LRFs), considerable effort has been directed toward identifying and finding solutions to the problems they face.[1] Much of this effort has focused on identifying enterprises that are profitable on a small scale; that is, enterprises which require little land and capital but provide a high return to the producer. These alternative crops include new and improved varieties of traditional cash crops and other nontraditional enterprises, such as fruits and vegetables, herbs and spices, ornamentals and specialty animals (French, Whatley).

The success of fruit and vegetable producers in California, Florida, Texas, and Arizona has triggered discussions as to whether other areas in the United States, particularly the southern states, could compete with these major producing states (Capps, Babb and Long). Coupled with this push for diversification is the belief that LRFs may benefit from alternative enterprises because they suffer adversely from price fluctuations and low net returns from production of traditional crops. Colette and Wall allude to the high income potentials of vegetables but argue that these crops tend to be very risky enterprises and that LRFs usually have insufficient cash reserves to carry them over a bad year.

Efforts have also been directed toward the marketing problems facing LRFs (Christy, Dagher, McLean-Meyinsse). While much attention has been given to alternative enterprises, a full understanding of the marketing system, including market risks, strategies, and alternative market outlets, requires more attention by producers, policy makers, and our profession. Most farmers allocate more time, energy, and resources to production than to marketing. Limited-resource farmers, in general, have not invested the resources required to identify and use viable marketing plans and strategies that can exploit the full potential gains these markets offer sellers of agricultural products. In some cases, LRFs have identified marketing niches and developed innovative marketing strategies (Wysong and Handwerker). The strategic behavior exhibited by small farmers has profit performance implications, such as (*a*) providing the consumer with high quality, usually fresh products, and (*b*) gaining the net margins that accrue from performing specific marketing services or functions.

The specific objectives of this paper are to (*a*) discuss the marketing system which LRFs are using to market alternative crops, including fruits and vegetables; (*b*) identify market institutions and market strategies evolving from this system and offer methods to evaluate their performance; and (*c*) recommend public and private strategic options and research priorities to improve the economic well-being of LRFs.

Market Channels Currently Used by Limited-Resource Farmers

Despite the potential for higher net returns from alternative enterprises, market access is one of the prerequisites for a successful LRF operation. Because fresh fruits and vegetables are highly perishable commodities, little time should elapse between harvesting and sale. In response to the obstacles embedded in the established market system, LRFs have resorted to nontraditional marketing channels to market their products. A brief discussion will now follow on typical wholesale and retail functions within the U.S.

Magid A. Dagher is an associate professor, Department of Agricultural Economics, University of Arkansas, Pine Bluff; Ralph D. Christy is a professor, Department of Agricultural Economics and Agribusiness, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center; Patricia E. McLean-Meyinsse is an associate professor, Department of Agricultural Economics, Southern University.

The authors are indebted to Enrique Figueroa, Roger Hinson, Albert Ade. Okunade, and Al Schupp for providing helpful comments at various stages of this study. The usual disclaimer applies.

[1] Although no universal definition for limited-resource farms (LRFs) exists, for this paper LRFs are designated by gross farm sales of under $40,000.

food market sector. Market opportunities that are available to LRFs at each level are discussed.

Wholesale Level

Wholesale activities for agricultural products in the United States are for the most part concerned with the sale of large quantities of produce to major buyers, such as chain stores, independent retailers, and processors. Thus, to be successful in wholesale market activities, farmers must have volume and quality as well as reputation for reliability. To overcome the difficulties involved in penetrating the established wholesale trade, LRFs have resorted to scaled-down wholesale activities, such as (*a*) pooling, (*b*) contract production, (*c*) store-door sales, and (*d*) cooperative marketing (Dagher).

Pooling arrangements provide an opportunity to amass volumes large enough to interest wholesalers, brokers, and processors. Farmers have also the additional benefit derived from standardization, quality, and packaging. Despite the potential advantages, LRFs are often reluctant to use pooling arrangements because many are unwilling to relinquish their independence.

Contract production provides farmers and buyers with advance knowledge on prices, product specification, and time and place of delivery. Under this marketing arrangement, a grower could protect himself from price volatility because price can be specified in the contract. Store-door sales are usually made direct to retail stores. With this method the farmer grades and transports the products to the stores. Finally, sales may be made through cooperatives. Marketing cooperatives can access markets which may not be available to individual growers. If the cooperative can obtain the resources, volumes, bargaining power, and marketing expertise, it could provide LRFs with the formula needed for successful marketing.

Retail Level

Retail activities have taken the following forms: roadside stands, pick-your-own operations (PYO), sales through farmers markets, and tailgating. Roadside markets can be successful if the products are of high quality, are competitively priced, and the stands are easily accessible from major highways. Pick-your-own operations provide an excellent opportunity for growers to reduce harvesting costs, particularly those associated with harvest packing and transportation. Success of a pick-your-own outlet depends on the grower's ability to attract consumers. A recently concluded study in Louisiana revealed that LRFs used the PYO methods quite frequently to market green beans, sweet corn, peas, yellow squash, strawberries, and watermelons (McLean-Meyinsse).

Farmers markets offer yet another opportunity for LRFs to sell direct to consumers. With the tailgating method, the farmer parks on a busy street or highway and sells from the back of his truck or may drive through neighborhoods and sell door-to-door. Despite these alternative marketing methods, LRFs possess limited market power. In light of this condititon, it is imperative that marketing strategies be developed and advanced to improve the economic condition of small farmers.

Marketing Strategies

Small-scale fruit and vegetable producers find themselves in an industry that faces enormous challenges at the commercial level in local, regional, national, and international markets. Mass retailing, and the accompanying volume and product standardization requirements, have increased the difficulties that LRFs face in trying to penetrate the established outlets for fruits, vegetables, and specialty animal enterprises.

Thus, it is essential to consider other strategies that LRFs may employ to improve market shares. The discussion will center around strategic behavior and market performance. Carlton and Perloff (pp. 400–401) define strategic behavior as consisting of the "actions by a firm to influence the market environment within which it competes, so as to increase the profits of the firm." Strategic marketing involves both strategic and tactical dimensions. Strategic decisions consider the market level at which the firm decides to compete (wholesale, retail). Tactical decisions include the use of the marketing mix (price, product, promotion, and place) to improve the firm's profits. Alternative marketing strategies that LRFs may use can be condensed into two categories: individual (noncooperative) and group (cooperative). A set of tactical options is presented for each major category.

Individual Strategies (Noncooperative Strategic Behavior)

Apart from the nontraditional marketing channels (farmers market, roadside, and PYO), LRFs have limited marketing options. However, some have expanded their marketing efforts to include more contractual and other arrangements with brokers, retail food stores, and institutional food services. Small and fledgling brokers are willing to do business with LRFs if their different volumes are treated as a pooled commodity base. This alternative would provide LRFs with some base to negotiate more favorable terms of trade. Under these conditions, LRFs' tactical options are constrained to improving the quality of their product because price, promotion, and place tactics are in the domain of the wholesale or retail buyer.

Group Strategies (Cooperative Strategic Behavior)

In addition to the wholesale marketing channels, LRFs may seek to establish bargaining associations, use agent middlemen, such as commission agents and brokers, employ advertising, and engage in vertical integration. The business structure being envisaged here is one of a cooperative corporation. The advantages of such group action would be to generate large volumes; impose quality control; improve storage, handling, and transportation; obtain the services of professional marketers and analysts; strengthen their bargaining position; establish themselves as reliable suppliers or processors; and command better prices.

Bargaining associations can also influence producer terms of trade by engaging in contractual negotiations with buyers. These farmer bargaining associations (with enabling legislation) would be comparable to the collective bargaining arrangements between labor unions and management. This idea is realistic because several fruit and vegetable bargaining associations already exist in the United States, particularly in the major producing states of California, Florida, and Texas.

Advertising, along with product differentiation, provides opportunities for market expansion. However, because most raw agricultural products are homogenous, effective advertising by any one group of farmers will be a major challenge. Advertising tends to be generic and other farmers (non-group members) derive some benefit also. However, advertising (along with branding) can be effective. For example, the brand name "Delta Fresh" could be used to identify Delta region fresh produce and may appeal to consumers in the region.

Finally, vertical integration offers opportunities for expanding markets and marketing activities. Vertical integration occurs when a firm combines several activities that are on different levels. The LRFs' realistic chances for successful integration could be in group action because the resource requirements for this marketing strategy are substantial. An integrated operation enables producers to exercise greater control of commodities as they move through the marketing system. Properly managed, integrated operations improve the profit position of producers. Again, by pooling resources, LRFs' bargaining positions are enhanced.

Market Performance

To identify relevant dimensions of economic performance, the agricultural economist draws from a branch of economics, industrial organization. Mainstream industrial organization theory focuses primarily on market structure, conduct and performance (Marion and Mueller, Scherer and Ross). The basic paradigm holds that the structure of a market (e.g., the degree of seller concentration) influences the conduct of firms (e.g., price competition), which in turn influences the resulting market performance (e.g., price efficiency). Market structure encompasses the environmental characteristics of an industry which influence the behavior of firms in the market place. Market performance appraises the economic results that market participants and society expect from the marketing system. Much of public debate and, thus, demand for economic information, concerns identification of relationships, if any, between the structure of a market and its resulting economic performance.

Elements of economic performance commonly used to evaluate markets are price efficiency, operational efficiency, product presentation, market access, price stability, and progressiveness (Marion and Handy). For each criterion, the researcher has established a norm against which the alternative institution can be evaluated. Traditionally, the competitive market has been used as the established norm. However, the applicability of the "perfectly com-

petitive" model to production agriculture is declining, as it has been for some time in most other sectors of our food system, and some researchers have questioned the desirability of such norms (Shaffer). Thus, given initial market conditions, the question is whether the market is moving in the direction of the "competitive" results. Another performance evaluation method is to identify the impacts of introducing an alternative market institution on the major actors within the system. This latter approach argues against the assumption of global efficient outcomes and seeks to provide information to decision makers as to the consequences of their alternative actions.

The performance impacts of alternative marketing institutions used by LRFs will evolve only with the passage of time and will be a major direction for future research. Any evaluation of economic performance must take into account at least two conceptual problems. First, performance is multidimensional. A choice must be made in selecting performance criteria; the appraisal of economic performance requires a distinction between economy-wide goals and policies on the one hand and criteria appropriate for individual industries on the other. Second, institutions are not designed to attain a final state or once-and-for-all formal objective; rather, they are aimed at ongoing pursuits by means of continuous assessment of specific effects and results. These objectives change over time. Thus, if innovative market institutions are indeed viable alternatives in directing market outcomes that are consistent with improving the economic conditions of LRFs and meet the preferences of the consumer, then research is needed to identify those institutions which hold the most promise.

Strategic Options and Policy Implications

This paper presented an overview of the nontraditional marketing system used by limited-resource farmers and advanced market strategies that are applicable to small-scale agriculture. Farmers were urged to become more market oriented by making contracts with market outlets so as to identify and respond to consumer preferences. It was also suggested that the LRFs should consider group action to improve their selective bargaining position. Contractual arrangements and bargaining associations, along with more aggressive advertising and product differentiation, are the keys to LRFs' market success.

Limited-resource farmers continue to survive despite tremendous economic odds. The market strategies presented can materialize only with the assistance of the land grant system and policy makers. Although there is a national need to improve the economic well-being of LRFs, solutions are often location specific. Therefore, as agricultural economists, we must address the problems that are indigenous to our region. Other land grant institutions besides the 1890s are directing research and extension towards LRFs, and we applaud these actions. However, more multidisciplinary approaches will be needed in order to find solutions to small-farm problems. We envision cooperative research activities among agricultural economists, extension personnel, plant and animal scientists, and sociologists to fully address the needs of LRFs.

Further public support of research and extension activities geared specifically toward evaluating innovative market institutions are needed. Initiatives that will encourage collective action by small farmers could be explored and then supported through the cooperative extension service and other existing market programs within state departments of agriculture. To date, many of these programs have been only marginally successful because of the inadequate levels of resources to implement them.

In the past, agricultural programs have benefitted the larger farmers; thus, policies should now be designed to benefit LRFs (West). If research is to be beneficial to LRFs, it should address the multidimensional goals of these farmers. Donald suggests that these needs could be addressed through educational and training programs within the land grant system. These programs would be designed to improve employable skills and increase family income and off-farm opportunities for limited-resource farmers, in particular, but for the entire rural populace as well.

References

Babb, E. M., and B. F. Long. "The Role of Alternative Agricultural Enterprises in a Changing Agricultural Economy." *S. J. Agr. Econ.* 19(1987):7–15.

Capps, Oral, Jr. "Changes in Domestic Demand for Food: Impacts on Southern Agriculture." *S. J. Agr. Econ.* 18(1986):25–36.

Carlton, D. W., and J. M. Perloff. *Modern Industrial Or-*

ganization. Glenview IL: Scott, Foresman and Co., 1990.

Christy, R. D. "The Small Farm Problem: Evaluating the Performance of Alternative Market Institutions." *Strategy for Survival of Small Farmers . . . International Implications*. Tuskegee AL: Tuskegee University Press, 1985.

Colette, W. A., and G. B. Wall. "Evaluating Vegetable Production for Market Windows as an Alternative for Limited Resource Farmers." *S. J. Agr. Econ.* 10 (1978):189–93.

Dagher, M. A. "Marketing Alternative Crops." *The Role of Agriculture in the Social and Economic Development of the Lower Mississippi Delta Region*. Proceedings of Regional Conference, Memphis TN, Feb. 1990.

Donald, S. L. "Small Farms: Factors Important to Their Survival." *Strategy for Survival of Small Farmers . . . International Implications*. Tuskegee AL: Tuskegee University Press, 1985.

French, F. M. "Small Animal Enterprises for Small Farms." *Research for Small Farms*. Washington DC: U.S. Department of Agriculture, Agr. Res. Serv. MP 1422, July 1982.

McLean-Meyinsse, P. E. "A Spatial Equilibrium Analysis of Small-Scale Produce Marketing in Louisiana." Paper presented at SAEA annual meeting, Fort Worth TX, Feb. 1991.

Marion, B. W., and C. R. Handy. "*Market Performance Concepts and Measures*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv. AER Rep. No. 244, Sep. 1973.

Marion, B. W., and W. F. Mueller. "Industrial Organization, Economic Power, and Food Systems." *Future Frontiers in Agricultural Marketing Research*, ed. Paul Farris. Ames: Iowa State University Press, 1983.

Scherer, F. M., and D. Ross. *Industrial Market Structure and Economic Performance*, 3rd ed. Boston: Houghton Mifflin Co., 1990.

Shaffer, J. D. "Does the Concept of Economic Efficiency Meet the Standards for Truth in Labeling When Used as a Norm in Policy Analysis?" *Economic Efficiency in Agricultural and Food Markets*, ed. R. L. Kilmer and W. J. Armbruster, pp. 91–98. Ames: Iowa State University Press, 1987.

West, J. G. "Agricultural Economics Research and Extension Needs of Small-Scale, Limited-Resource Farmers." *S. J. Agr. Econ.* 11(1979):49–56.

Whatley, B. T. "Small Farms System for Efficient Horticultural Production." *Research for Small Farms*. Washington DC: Agr. Res. Serv. MP 1422, July 1982.

Wysong, J. W., and T. S. Handwerker. "Managing Assets on Small or Limited Resource Farms." *Yearbook of Agriculture*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv., 1989.

Limited Resource Farmers: Discussion

Handy Williamson, Jr.

The title of Davis's paper promised an opportunity to review and interpret some insightful and thoughtful angles on how U.S. farm policy has impacted limited resource farmers (LRF's). With some imagination, one could anticipate explanations or points of view on (*a*) how policies directed specifically at LRFs have impacted their status; (*b*) how policies directed toward commodities and commercial farms have indirectly impacted the status of LRFs; (*c*) how a policy of benign neglect has endangered or abused LRFs; or (*d*) how the voiceless, powerless, and advocateless LRFs are excluded from the policy-making process, etc. Unfortunately, Davis did not provide adequate coverage of any of these points. Furthermore, he did not provide supportable evidence to undergird the notions presented, and he did not stay within the implied scope of the paper.

However, Davis did make several points which deserve to be recognized and addressed with greater breadth and intensity. They also justly deserve attention from agricultural economics professionals. Those points are addressed by this discussion from a framework of where they were found in Davis' paper.

Point (*a*): No attempt was made by Davis to delineate the shortcomings of agricultural economics as a profession involving these issues. I find this curious, especially as I read in the paper notions that (*i*) agricultural economists have failed to address human issues in the agricultural sector; (*ii*) the agricultural economics profession has not appropriately addressed differences in resource endowment among farmers; (*iii*) most agricultural economists are employed by large universities which are inclined to address the needs of agribusiness; (*iv*) individuals in the profession are more concerned about income, fame, and personal success than for limited resource farmers.

It would seem that these are in fact implied shortcomings or at least short-sighted considerations which have caused us not to adequately address the needs, not only of limited resource farmers, but of the disadvantaged cast-offs of our agricultural system.

Handy Williamson, Jr., is a professor and Head, Department of Agricultural Economics and Rural Sociology, University of Tennessee.

Role of Agricultural Economics

Point (*b*): Limited resource farmers are disadvantaged and require some form of welfare or income transfer policies and procedures to mitigate their inequity. This point was hoisted as a "goal" of farm policy, under an "if, then" conjecture to obviate a role for agricultural economists to address how well the agricultural system has (is or will) responded (respond). Such benevolent welfare or income transfer has never been, and unfortunately never will be, the goal of agricultural policy, at least in the direction of from the "haves" to the "have nots." Davis implies that agricultural economics has failed to address the issues. Perhaps in failing to do so we have failed to remind the policy establishment of missed opportunity to demonstrate equity and fairness in the exercise of chosen policies.

Point (*c*): Agricultural economists, in general, focus their attention and analytical abilities on problems and concerns of the agribusiness and large commercial farmers. They are influenced "by the large universities whose main mission is to serve the agribusiness sector of the state and the nation." Agricultural economists, in my opinion, have not restricted their focus to agribusiness and the commercial farming sector. By checking the AAEA directory, we see that more agricultural economists cite farm management and production economics, and rural development than cite marketing and agribusiness. By checking the journals and proceedings of various conferences and by reviewing activities described in newsletters, etc., one gets the sense that our interest is more diverse than Davis's assertion would suggest. Increasingly, our atten-

tion is turning to the environment, consumers, and food safety.

Policy Formation Process

Point (*d*): The "decline in the numbers of limited resource farmers . . . coupled with the growth in the commercial farm group and the emergence of other interest groups, has lessened the influence and potential impact of limited resource farmers in farm policy formation." The emergence of stronger concern for the environment coupled with greater knowledge and activity of advocacy groups will increasingly influence farm and food policy and brunt the impact wielded by agribusiness and commercial farms. In the not-too-distant future, a climate of support and acceptance for small sustainable and organic farms and systems will likely emerge. Policy and program shifts will follow suit to become more "technologically and socially correct."

The 1990 Farm Bill

Point (*e*): The 1990 farm bill is land based, has hurt land-poor LRF while helping land-rich farmers. The structure of U.S. agricultural policy has been tilted toward larger-scale production-efficient and technology-adopting farmers. One cannot quarrel with this point. One can suggest that many realities regarding who benefits or suffers from our farm policy have been ignored or displaced along the way. The decision to tie support and other payments to the land, at the very outset, was a political (not technical) decision crafted to avoid backlash which would result from transfer payments to sharecroppers and other tenancy groups. This decision ignored the fact that the largest farmer group (in the post-reconstruction U.S.) were nonlanded sharecroppers and tenants. Also ignored along the way were data which suggested superior return per acre on tenant farms associated with familiarity and superior knowledge of cultural practices.

Role of the 1890 Universities

Point (*f*): These universities have been understaffed and underfunded and allowed only limited resource farms as a claimed area of agricultural research expertise. Student numbers, teaching loads, and resource scarcity have hampered their ability to address LRFs' concerns. This is an accurate assessment of the distant past. In recent years, fiscal support at the federal level has allowed the 1890s to build capacity and more forcefully address research on small farm problems, in addition to problems confronting the rural and urban disadvantaged segments of our society. If and when the day of funding parity (equity) emerges, one can expect the scope, intensity, and volume of LRF research at the 1890s to improve. However, LRF problems should not be the only research focus areas for the 1890 agricultural economists. To do so would be, indeed, short-sighted.

Because of unique commitments and sensitivities, the 1890s will likely continue leading the U.S. agricultural research system's focus on the needs of limited resource farmers.

Some Strategies and Suggestions

There are four strategies Davis suggests to help improve the lot of limited resource farmers:

(*a*) Farmers become (activist) involved in policy formation and implementation process; organize and develop support groups.

(*b*) Professional agricultural economists should play a role after a paradigm ("Paradiem") shift has been made within the profession.

(*c*) New incentives should be developed in the land grant system to encourage a new approach to small farm problems.

(*d*) Develop new economic models that do not depend on "growth" as an essential criterion for success. This would be the real challenge.

These are not "bad" strategies. They are, in fact, highly acceptable. However, they are nearly 50 years too late. Considering the size of the small farm population and the propensity of American consumers to consume "hard tomatoes" even during tough times, I would say that the recommendations of this paper are tantamount to closing the barn door once the mule is out to pasture.

Limited Resource Farmers and the Marketing System: Discussion

Tesfa G. Gebremedhin

The authors of the papers in this session have been asked to discuss an important and controversial issue. Today there is no forum to aggressively articulate or advance the unique concerns and interests of the least organized and mostly forgotten group of farms. Little attention has been received from policy makers to address problems impeding the economic improvements of limited resource farms.

The authors of the paper on marketing systems are to be commended for making great effort to address the unique problems of limited resource farms. Their sincerity and conviction to the issue are beyond question. However, presenting case studies with practical solutions or success stories of market practices by limited resource farmers could strengthen the outlook of the paper. Traditionally, the definition of limited resource farms as farms grossing farm sales of under $40,000 has not provided the opportunity for more accurately targeting needed adjustments and development in policy. Limited resource farmers are a part of the diversity of rural America, and their structural characteristics vary by type of operation, purpose of farming, and geographic location. This diversity in the characteristics suggests that limited resource farms vary in their resource endowments and enterprise combinations and their interaction with the nonfarm sector (Gebremedhin).

The authors indicated that there are obstacles embedded in the established market system for limited resource farmers. Limited resource farmers are confronted with many problems because they produce in an industry geared toward serving large-scale production units. One of the problems facing limited resource farmers is the increase in input prices. Large farmers typically can buy farm inputs in bulk amounts at lower prices than limited resource farmers. Their advantage may result from simple market power from their size in relation to the supplier's market or to actual lower cost for suppliers moving a volume to an individual producer. Changes in input prices are the result of change in basic supply and demand conditions for inputs, as well as the changes in competitive conditions in the input market which affect the relative competitive positions of farm operations (West).

The other obstacle in the established market system is the general development in marketing services which include developments in transportation and storage facilities, the advent of mass retailing patterns, the accompanying volume specification and grade standardization requirements, integration of segments in the production and marketing system and public regulation of marketing activities. These technological developments and changes in the marketing structure have significant impacts upon the survival of limited resource farmers. Changes in marketing practices influence the structure of the assembly and processing systems and thus influence access to markets for both inputs and outputs. Limited resource farmers are seldom in a position to benefit directly from higher product prices and expanding markets. Limited resource farmers do not produce enough output to influence prices, and they have usually incurred high input costs relative to large farmers. Marketing firms have turned to larger farmers or developed an integrated marketing system into which limited resource farmers cannot penetrate or compete in the marketing process. Limited resource farmers, with their relatively low volumes and bargaining powers, have found it difficult to gain access to this centralized system on an individual basis. Pooling arrangements of production through cooperatives to gain the advantage of a mass volume require a substantial portion of total supply of the product market. Generally, limited resource farmers have little potential to form cooperatives and strengthen their bargaining power.

Nontraditional marketing channels offer a number of tactical market options, especially if they are creative in their approach. However, limited resource farmers often possess a limited market share. Vertical integration, bargaining

---

Tesfa G. Gebremedhin is an associate professor of agricultural economics at West Virginia University.

associations, and cooperatives work best for large farmers and have been less effective for limited resource farmers because they lack market information, marketing skills, access to the market, economies of scale, and face institutional barriers. Limited resource farmers have limited marketing options because they have worked in an environment that has been almost impervious to technological changes and public policies. Thus, it is essential to do further research to understand their unique problems and search for viable development strategies that limited resource farmers can exploit to their full potential.

The changing structure of production agriculture, characterized by technological development and economic changes has brought repeated changes in the economic and natural bases of farming. Emerging modern agricultural technology will move and change the structure of agriculture in the same profound ways and directions in the future as before—toward more sophisticated and challenging management and marketing, larger and fewer commercial farms, greater capital intensity, and greater separation of management and ownership (Tweeten). Limited resource farmers are not in a position to benefit directly or indirectly from the technological developments in marketing and production practices. Thus, farms with limited productive resources and marketing skills likely will cease to exist unless public policy responds to their unique and distinct social and economic problems. Public policy may be apropriate for limited resource farmers because public policy concerns itself with people who are not likely to benefit from market or nongovernmental forces (Marshall and Thompson).

Limited resource farms represent enterprises which largely have been ignored by public policy, both agricultural and economic, and operate in an environment geared toward serving and benefiting large farms (Gebremedhin and Johnson). Current government policies have not and will not preserve limited resource farms (Tweeten). Government programs have done and can do little to solve their genuine problems because the programs are not necessarily applicable to these impoverished rural people (Marshall and Thompson). Thus, increasing agricultural income on limited resource farms is a reasonable policy goal that is in the best interest of the nation. Resolving the problems peculiar to limited resource farms clearly requires knowledge about their farm production and marketing. There is the need to design policies and install institutions so that limited resource farmers may gain access to cost-reducing technology and knowledge, off-farm employment opportunities, human resource development (education), and community development programs that complement a more diverse agriculture and rural community base.

References

Gebremedhin, Tesfa G. "Assessing the Impacts of Technology on Southern Agriculture and Rural Communities." *S. J. Agr. Econ.* 20(1988):45–52.

Gebremedhin, Tesfa G., and William M. Johnson. "Small Farm Research and Policy Implications." *S. J. Agr. Econ.* 17(1985):47–56.

Marshall, Ray, and Allen Thompson. *Status and Prospects of Small Farmers in the South.* Atlanta GA: Southern Regional Council, 1976.

Tweeten, Luther G. "Agricultural Technology—The Potential of Socioeconomic Impact." Paper AE8680 presented to Oklahoma Network for Continuing Higher Education leadership development seminar on "Agriculture and the Expanding Kowledge Base." Stillwater OK, 2 Oct. 1986.

West, Jerry G. "Agricultural Economics and Extension Needs of Small-Scale Limited-Resource Farmers." *S. J. Agr. Econ.* 11(1979):49–56.

Agricultural Economics and Limited Resource Farmers' Production Decisions: Discussion

Dewitt Jones

Over the past quarter century, there has been a sustained increase in interest in limited resource, or small farmers. This increased interest has been accompanied by an increase in effort to identify and find solutions to the problems faced by this group of farmers. Nelson, Brown, and Toomer have attempted to shed additional light on whether limited resource farmers are as efficient in the use of their resources as commercial farmers.

To test this hypothesis, the authors used a sample of 116 farmers, comprised of 71% limited resource farmers and 29% commercial farmers, drawn from two contiguous south Georgia counties. A log-linear Cobb-Douglas production using generalized least squares regression analysis was then used to examine the physical economics of size (technical) and allocative efficiency in the use of resources between the two classes of farmers.

They found that the elasticity of production for two of the resources included in the model (land and machinery) differed significantly, but no significant difference existed between the two classes of farmers for the other resources. They concluded that these differences suggest that limited resource farmers are represented by different production functions. However, they go on to state that no significant difference was found to exist in the cumulative elasticity of production between the two classes of farmers. The authors conclude that "the most recent work seems to suggest that both types of farms are fairly efficient in the use of resources . . . [and] the results of this study also tend to support this view." I draw from their conclusion, in terms of my interpretation of the issue that was to be discussed, that the agricultural economics profession has served limited resource farmers about as well as commercial farmers with respect to decision making on the use of resources.

Two other findings reported by the authors were quite interesting and important to decision making by limited resource farmers. The first was that limited resource farmers were found to use about $16 less per acre on fertilizer and chemicals but generated about $60 less in output per acre than commercial farms. Thus, by increasing expenses by $16 per acre, limited resource farms could increase their net farm income by $44 per acre, almost a 3:1 net return per dollar invested. The other finding I think was important was the difference in gross farm, and in turn net farm, income between the two classes of farmers. The commercial farmers in the sample had average annual gross farm income of approximately $112,000 compared to $17,000 for limited resource farmers. Using the figure that it takes approximately $.70 in expenses per dollar of gross farm sales (USDA, National Financial Summary), the commercial farmers had an average annual net farm income of approximately $34,000 compared with $5,100 for the limited resource farmers. The average annual net farm income of the commercial farmers is sufficient to provide a minimum adequate standard of family living, whereas the level generated by the limited resource farmers would place the typical family at or below the poverty line, if this were its only source of income.

In conclusion, the findings reported by Nelson, Brown, and Toomer suggest that the agricultural economics profession, given its perceived responsibilities, has not neglected limited resource farmers; their incomes could be increased somewhat by improving their production decisions, but they would continue with incomes at or below the poverty line if they remain limited resource farmers without some other source of income. Thus, if the goal is to significantly improve the economic well-being of limited resource farmers, the options for doing

Dewitt Jones is a professor in the Department of Agricultural Economics, Southern University.

so are quite clear. They are to (*a*) significantly increase the size of operation, (*b*) secure income from off-farm sources, or (*c*) pursue a combination of the two options. USDA reports and U.S. Census of Agriculture data reveal that the majority of limited resource farmers are pursuing option (*b*). For example, slightly under 60% of limited resource farmers have occupations other than farming as their principal occupation (Census of Agriculture) and off-farm income accounts for at least 70% of net cash family income (USDA, *National Financial Summary*). Moreover, Johnson and Banker, in a study of factors farmers consider in making management decisions, found that at least 60% of farmers with sales less than $40,000 ranked increasing size of operation, improving efficiency, or reducing cost low to moderate in importance. On the other hand, over 80% ranked living on a farm moderate to high (63% gave this item a high ranking) in importance in their management decisions. Thus, as numerous studies indicate, the plight of limited resource farmers is more dependent on the nonfarm sector of the economy than the farm sector (Henry). This suggests that the focus of our effort should be on improving the economic well-being of limited resource farmers, not just on their farming operations.

References

Henry, Mark S. "Southern Farms and Rural Communities: Developing Directions for Economic Development Research and Policy." *S. J. Agr. Econ.* 20(1988):13–28.

Johnson, Jim, and David Banker. "What Do Farmers Consider Important When Making Management Decisions?" *Agricultural Income and Finance Situation and Outlook*. Washington DC: U.S. Department of Agriculture, Econ. Res. Serv., Rural Econ. Div. AFO-41, June 1991.

U.S. Department of Agriculture, Economic Research Service, Agriculture and Rural Economy Division. *Economic Indicators of the Farm Sector: National Financial Summary, 1989*. Washington DC, Jan. 1991.

U.S. Department of Commerce, Bureau of the Census. *Census of Agriculture: 1987*, vol. 1, *Geographic Area Series*, pt. 51, United States. Washington DC, 1987.

Consumer's Surplus versus Compensating Variation Revisited

Jeffrey T. LaFrance

Economics involves the estimation of costs and benefits. For single good demand models, Hausman has shown that, when deadweight losses are of interest, exact welfare measures can reduce measurement errors substantially relative to consumer's surplus approximations. A comparable statement has yet to be made when the focus of the analysis includes several demand equations. This issue is complicated by the fact that computing exact welfare measures for several goods requires the structure of the theory of consumer choice. The popular term for this structure is integrability.

It is well known that integrability of the demands is necessary and sufficient for the existence of the exact money metrics compensating and equivalent variation. Even the approximation arguments for the use of consumer's surplus (Willig) are based on the assumption that an underlying preference function exists. This seems to suggest that integrability ought to be taken seriously by empirical demand analysts. On the other hand, it is convenient to specify demand equations as ad hoc functions of the prices of the goods of interest, the prices of closely related goods, income, and a small set of demographic or other shift variables. The demand functions are transformed, if necessary, to a form that is linear in the unknown parameters and the model estimated by standard least squares estimation methods.

Some of my past research has focused on the theoretical structure of incomplete demand models (LaFrance 1985, 1986, 1990; LaFrance and Hanemann). *Inter alia,* I have argued in this work that the theoretical implications of many of the common ad hoc demand models are so severe that this approach is not as attractive as it first appears to be. However, one question that commonly was raised during the course of this work is, "Just how important is it to estimate demand models that satisfy the rigorous and generally nonlinear restrictions of integrability?" This question is the focus of the present paper.

In the paper I briefly discuss three approaches to welfare measurement with subsystems of demand equations. The three approaches differ in their treatment of the implications of utility maximization on the demand equations. The first approach, consumer's surplus, does not impose the theoretical restrictions on the data at all. Rather, a substitute restriction is applied to ensure that a unique welfare measure is obtained. This restriction is symmetry of the cross-price derivatives of the ordinary demand functions (Burt and Brewer; Chiccetti, Fisher, and Smith; LaFrance and de Gorter). The second approach, which I call linear compensating variation, imposes the integrability restrictions at a single point of the data, say, the sample means (Chavas; Huang and Haidacher; and Safyurtlu, Johnson, and Hassan). The quantities demanded are the first-order partial derivatives of the expenditure function with respect to prices, while the Slutsky substitution terms are the second-order partial derivatives. Consequently, at the point of Slutsky symmetry for the demand equations, we can apply Taylor's theorem to obtain a quadratic expansion of the expenditure function with respect to prices. This allows us to approximate the exact compensating variation of a price change from the base point to second order, in line with the arguments suggested by Burt and Brewer. The third approach is weak integrability. This approach imposes the theoretical restrictions on the demand functions over a range of values of the data. This approach permits the recovery of the dual preference structure for the goods of interest and the calculation of the exact welfare measures for changes in the prices of those goods (LaFrance and Hanemann). Its main drawback is that the integrability restrictions are nonlinear in the parameters.

I also undertake a comparison of the relative

The author is a professor of agricultural economics at the University of Arizona.

merits, or lack thereof, of the three different approaches. The comparison utilizes a system of five demand equations for the per capita consumption of U.S. dairy products over the period 1950 through 1985. The functional form for the consumer's surplus and linear compensating variation models is linear in the variables and in the parameters, which is a common choice for multiproduct welfare analyses (Burt and Brewer; Chicchetti, Fisher, and Smith; Freebairn and Rausser; LaFrance and de Gorter). The restrictions for both of these models are also linear in the parameters, which is convenient for estimation. The linear model is convenient for one other reason. It permits the empirical application of a newly discovered weakly integrable incomplete demand model that has the same number of parameters with comparable restrictions as the consumer's surplus model, although the integrable model is nonlinear in the parameters (LaFrance 1990).

The results of the empirical comparison are consistent with, but stronger than, the results of previous work involving single demand equations. Because per capita demands for dairy products are very price and income inelastic, the lion's share of the consumer welfare effects of the retail price distortions resulting from the dairy program are income transfers away from consumers. These transfers are common to all of the welfare measures compared in the study. As a result, the magnitude of the total change in consumer welfare is similar across the different measures (Willig). However, the normative economic evaluation of policies focuses on the deadweight loss to consumers (Hausman). With this metric, the linear consumer's surplus deadweight loss is less than 17.5% of the compensating variation measure. The linearized compensating variation deadweight loss is nearly twice the size of the exact measure and has the wrong sign!

The differences between the linear approximations and the theoretically correct measure are caused in part by the fact that linear estimation methods cannot impose curvature restrictions on the ordinary or compensated cross-price effects. To isolate this effect, a fourth model was estimated. This model was restricted to have a symmetric, negative semidefinite matrix of ordinary cross-price effects. This restriction improved the performance of the consumer's surplus approximation considerably. The new estimate of deadweight loss is 115% of the compensating variation measure. But there are two good reasons not to use this approximation. First, although 15% does not appear to be large, it is an unnecessary error. Second, the parameter restrictions for the concave consumer's surplus model are nonlinear and as difficult to impose as integrability.

Welfare Measurement with Incomplete Demand Systems

Throughout the paper I employ notation similar to that in my previous theoretical work on incomplete demand systems, which is summarized here. Let $x = [x_1, \ldots, x_n]'$ be the vector of the goods of interest and $p = [p_1, \ldots, p_n]'$ the corresponding price vector; let $z = [z_1, \ldots, z_m]'$ be the vector of all other commodities and $q = [q_1, \ldots, q_m]'$ the corresponding price vector; let $s = [s_1, \ldots, s_k]'$ be a vector of demographic or other demand shifters; and let income be y. We estimate the n demands for x,

$$(1) \qquad x = h(p, q, y, s),$$

but we neither observe nor estimate the demands for z. It is assumed throughout that all prices and income are deflated by a linear homogenous function of the prices of the other goods. Thus, (p, q, y) are interpreted as "real" prices and income.

In the empirical application, x is the per capita annual consumption of the following five dairy products: fresh milk and cream, butter, cheese, frozen dairy products, and other dairy products (evaporated and nonfat dry milk). The deflator for all prices and income is the consumer price index for nonfood items, and the income measure is per capita disposable income. The prices of other goods included in the empirical demand equations are the consumer price indices for nonalcoholic beverages (coffee, tea, cocoa, and carbonated soft drinks), for fats and oils (margarine, salad dressings and cooking oils, and lard), and for meats, poultry, and fish. The demographic shift variables are the mean, variance, and skewness of the age distribution of the U.S. population.

Consider a change in the prices of x from p_0 to p_1 with (q, y, s) held constant. Specifically, we are interested in the economic welfare costs for U.S. consumers of the retail price effects of the federal dairy program. The consumer's surplus measure of the effects of this price change, cs, is defined by the line integral,

$$(2) \qquad cs = -\int_{p_0}^{p_1} h(p, q, y, s)'dp.$$

This measure is uniquely defined for any monotonic path from p_0 to p_1 if and only if the ordinary cross-price derivatives are symmetric,

$$(3)\quad \partial h^i(p, q, y, s)/\partial p_j = \partial h^j(p, q, y, s)/\partial p_i, \quad i, j = 1, \ldots, n.$$

For the linear demand model employed in the next section,

$$(4)\quad h(p, q, y, s) = \alpha + A_q q + A_s s + Bp + \gamma y,$$

where α is an $n \times 1$ vector, A_q is an $n \times m$ matrix, A_s is an $n \times k$ matrix, B is an $n \times n$ matrix, and γ is an $n \times 1$ vector of parameters, consumer's surplus is well-defined if and only if B is symmetric, $B = B'$. When the demands for x are weakly integrable, the relationship between consumer's surplus and exact welfare measures is examined in detail in LaFrance and Hanemann. Without integrability, however, it is unclear what relationships, if any, exist between consumer's surplus and other potential welfare measures. As noted in the introduction, the attractions of consumer's surplus, especially in terms of the linear demand model (4), are that the empirical model and implied parameter restrictions are easy to estimate and impose and the consumer's surplus line integral is easy to calculate; it is a simple quadratic form in prices.

Burt and Brewer argued that consumer's surplus provides a second-order approximation to the expenditure function, $e(p, q, u, s)$, in p-space. This is strictly true only if the income effects for the demands for x are zero, because in general the Slutsky matrix, that is, the $n \times n$ matrix of compensated substitution effects for x,

$$(5)\quad S \equiv \partial h/\partial p' + \partial h/\partial y h',$$

is the Hessian matrix of the expenditure function with respect to p. However, the idea of a quadratic approximation to indirect preferences as represented by the expenditure function is appealing. The reason is that if (5) is imposed on the estimation problem at the point p_0, then Taylor's theorem implies that a second-order approximation to the expenditure function exists around that point in the form

$$(6)\quad e(p, q, u, s) \approx e(p_0, q, u, s) + \frac{\partial e(p_0, q, u, s)}{\partial p'}(p - p_0) + \frac{1}{2}(p - p_0)' \frac{\partial^2 e(p_0, q, u, s)}{\partial p \partial p'}(p - p_0).$$

Hotelling's lemma implies that $x_0 = \partial e(p_0, q, u, s)/\partial p$. On the other hand, the duality between the expenditure function and the indirect utility function implies that

$$(7)\quad \partial e(p_0, q, u, s)/\partial p \equiv h(p, q, e(p_0, q, u, s), s).$$

Therefore, the Slutsky matrix evaluated at the point (p_0, q, u, s),

$$(8)\quad S_0 = \frac{\partial h(p_0, q, e(p_0, q, u, s), s)}{\partial p'} + \frac{\partial h(p_0, q, e(p_0, q, u, s), s)}{\partial y} \times h(p_0, q, e(p_0, q, u, s), s)',$$

is the $n \times n$ matrix of second-order terms for the quadratic expansion.

The exact compensating variation for the price change, cv, is defined by

$$(9)\quad v(p_0, q, y, s) = v(p_1, q, y - cv, s),$$

where $v(p, q, y, s)$ is the indirect utility function. Setting both sides of (9) equal to u and solving for the expenditure function provides an equivalent expression for compensating variation in terms of the expenditure function

$$(10)\quad cv = e(p_0, q, u, s) - e(p_1, q, u, s).$$

Combining (6) through (10), we obtain a second-order approximation to compensating variation, cv, as

$$(11)\quad cv \approx -\left[x_0'(p_1 - p_0) + \frac{1}{2}(p_1 - p_0)' S_0 (p_1 - p_0)\right].$$

For the linear demand model (4), the local symmetry conditions are linear in the parameters,

$$(12)\quad B + \gamma x_0' = B' + x_0 \gamma'.$$

This implies that the cv approximation (11) can be obtained conveniently with standard linear estimation methods subject to linear constraints. This is the rationale for calling this measure linear compensating variation. Equation (11) is a precise statement of the quadratic approximation to the expenditure function in p-space advocated by Burt and Brewer.

In my first work on incomplete demand models, I found that linear demand models with

non-zero income effects are weakly integrable if and only if the model parameters satisfy extreme parameter restrictions (LaFrance 1985). These restrictions imply that all of the goods with linear demands are perfect complements, which makes the linear model an unreasonable choice for exact welfare measurement. For comparison purposes, it is desirable to have an integrable model with the same number of parameters and a roughly equivalent degree of flexibility as the linear consumer's surplus model with symmetric price effects. Fortunately, I recently stumbled across just such a model by considering the integrability conditions for models that are linear in income and linear and quadratic in prices (LaFrance 1990). This model specification is

$$(13)\quad h(p, q, y, s) = \alpha + A_q q + A_s s + Bp + \gamma\left(y - \alpha' p - p' A_q q - p' A_s s - \frac{1}{2} p' B p\right).$$

The number of parameters in (13) is the same as the number in the linear demand model (4). Also, it is straightforward to show that the Slutsky substitution matrix is $S = B + \bar{y}\gamma\gamma'$, where $\bar{y} \equiv y - p'(\alpha + A_q q + A_s s) - 1/2\, p'Bp$, so that symmetry of S is equivalent to symmetry of B. Thus, the integrable model (13) has the same number and form for the symmetry restrictions as the linear consumer's surplus model. However, integrability also requires the Slutsky matrix to be negative semidefinite, leading to nonlinear restrictions between the parameters. Implementation of these restrictions is discussed in the next section.

The quasi-indirect utility function for the demand model (13) is

$$(14)\quad \varphi(p, q, y, s) = \left(y - p'(\alpha + A_q q + A_s s) - \frac{1}{2} p' B p\right) e^{-\gamma' p}.$$

This gives the exact compensating variation for the change in prices from p_0 to p_1 as

$$(15)\quad cv = \left(y - p_1'(\alpha + A_q q + A_s s) - \frac{1}{2} p_1' B p_1\right) - \left(y - p_0'(\alpha + A_q q + A_s s) - \frac{1}{2} p_0' B p_0\right) e^{\gamma'(p_1 - p_0)}.$$

The next section compares the compensating variation measure (15) obtained by estimating the nonlinear demand model (13) subject to symmetry and negative semidefiniteness of the Slutsky matrix, $S = B + \bar{y}\gamma\gamma'$; consumer's surplus,

$$(16)\quad cs = p_0'(\alpha + A_q q + A_s s + \gamma y) - \frac{1}{2} p_0' B p_0 - p_1'(\alpha + A_q q + A_s s + \gamma y) - \frac{1}{2} p_1' B p_1,$$

obtained by estimating the linear demand model (4) subject to symmetry of the price effects matrix, B; and linear compensating variation (11), obtained by estimating the linear demand model subject to the local Slutsky symmetry conditions (12).

An Empirical Application to the U.S. Dairy Program

For our empirical application, data on average annual retail prices for fresh whole milk, butter, cheese, ice cream, and evaporated milk were collected from several Bureau of Labor Statistics (BLS) and U.S. Department of Agriculture (USDA) sources. Data on the U.S. population by ten-year age groups were obtained from the 1990 *Economic Report of the President, Historical Statistics of the United States, Colonial Times to 1970,* and several issues of *Statistical Abstracts of the United States*. Data on the civilian unemployment rate, the average wage rate for manufacturing workers, the producer price indices for manufacturing materials and for fuels and energy, the rate of return on AAA corporate bonds, and per capita disposable income were obtained from the 1990 *Economic Report of the President*. Per capita annual consumption of U.S. dairy products was obtained from the USDA series *Food Consumption, Prices, and Expenditures*. Consumer price indices for dairy products, nonalcoholic beverages, fats and oils, meats, poultry, and fish, and nonfood items were obtained from the 1978 *Handbook of Labor Statistics* and the 1978 through 1986 January issues of the BLS publication, *CPI: Detailed Report*. Space limitations preclude a more detailed discussion of the data here. A complete description of the original data and all transformations is available upon request.

From the standpoint of the effects on retail prices for dairy products, the structure of the U.S. dairy program has not changed since the 1949 Agricultural Adjustment Act. The federal government intervenes in the dairy market in two ways. In the market for Grade A milk, that is,

milk that meets the sanitary requirements to be legally sold for use in fresh milk products, federal milk marketing orders enforce price discrimination. Processors and handlers are required by law to pay a higher price to farmers for Class 1 milk, which is used for fresh milk and cream, than for Class 2 milk, which is used for manufactured dairy products such as butter, cheese, and powdered milk. This requirement has the effect of increasing producer revenues, stimulating supply, and leading to a surplus of Grade A milk production that "spills over" into the Grade B market, the market for milk that can be used only in the production of manufactured dairy products. In both the Grade A and Grade B markets, the federal government supports the farm price of manufacturing milk by purchasing at the wholesale level butter, cheese, and nonfat dry milk at announced prices determined by the farm-level support price for manufacturing milk (hereafter, Class 2 milk) and estimated manufacturing costs of production for those products. Over the period 1953 through 1980, the net effect of these two programs at the farm level has been to increase the farm-level Class 1 price by about 17% and reduce the farm-level Class 2 price by about 14% (LaFrance and de Gorter).

The wholesale to retail price linkage regression equations for identifying the net retail price effects of the U.S. dairy program are reported in table 1. In table 1, the retail prices of dairy products are predicted by the following factors: (*a*) a set of general economy variables—the civilian unemployment rate (*Unem*), manufacturing wage rates (*Wage*), producer price indices for manufacturing materials (P_{mtl}) and for fuels and energy (P_{fuel}), and the real rate of return on AAA corporate bonds (r_{bond}); (*b*) the mean (*Avg*), variance (*Var*), and skewness (*Skew*) of the age distribution of the U.S. population; (*c*) the farm and wholesale government dairy price variables—government purchase prices for butter (GP_{btr}), cheese (GP_{chs}), and nonfat dry milk (GP_{dm}), the average minimum Class 1 milk price (S_1), and the average support price for Class 2 milk (S_2); and (*d*) the consumer price indices for fats and oils (P_{fat}), nonalcoholic beverages (P_{bev}), and meats, poultry, and fish (P_{meat}). All prices are deflated by the consumer price index for nonfood items. The real rate of return on corporate bonds, r_{bond}, is constructed as follows:

$$(16) \quad r_{bond,t} = 1 - \left(\frac{1 + i_{bond,t}}{1 + 2(cpi_{nf,t} - cpi_{nf,t-1})/(cpi_{nf,t} + cpi_{nf,t-1})}\right),$$

where $cpi_{nf,t}$ is the consumer price index for nonfood items in year t and $i_{bond,t}$ is the nominal rate of return on AAA corporate bonds. The consumer price index for nonfood items was used to generate all of the real price variables in order to employ a broadly defined deflator without introducing any unintended simultaneity problems between the left- and right-hand-side variables in the regression equations. Per capita disposable income is not included among the regressors for the retail price equations because of extreme multicollinearity. The condition index for the scaled matrix of variables including the above list, an intercept, and real per capita disposable income is 7445. Belsley, Kuh, and Welsh, and Belsley provide evidence that multicollinearity leads to numerical problems with condition indices as low as 100. Regressing income on the other explanatory variables results in a nearly perfect fit ($R^2 = .9992$).

The second part of the empirical analysis links the farm-level goals of the federal dairy program to the government purchase prices with three regression equations that predict the government purchase prices for butter, cheese, and nonfat dry milk with the farm-level support price for Class 2 milk and the prices of other manufacturing inputs. The results are

$$\underset{}{P_{btr}} = \underset{(1.56)}{11.2} - \underset{(.417)}{2.42}*Wage - \underset{(.242)}{.320}*P_{mtl} - \underset{(.188)}{.814}*P_{fuel} + \underset{(.156)}{1.11}*S_2 + \underset{(.124)}{1.53}*u_{-1} - \underset{(.124)}{.666}*u_{-2}$$

$$R^2 = .984 \qquad s = .157 \qquad DW = 1.96$$

$$P_{chs} = \underset{(.426)}{-.587} + \underset{(.0729)}{.502}*Wage + \underset{(.0970)}{.00187}*P_{mtl} - \underset{(.0430)}{.121}*P_{fuel} + \underset{(.0503)}{.954}*S_2 + \underset{(.154)}{.379}*u_{-1}$$

$$R^2 = .979 \qquad s = .0803 \qquad DW = 1.62$$

$$P_{dm} = \underset{(1.05)}{-4.53} + \underset{(.274)}{1.15}*Wage + \underset{(.180)}{.275}*P_{mtl} + \underset{(.127)}{.406}*P_{fuel} + \underset{(.108)}{.460}*S_2 + \underset{(.161)}{1.13}*u_{-1} - \underset{(.124)}{.259}*u_{-2}$$

$$R^2 = .983 \qquad s = .113 \qquad DW = 2.09$$

Table 1. Wholesale-to-Retail Price Regressions for the U.S. Dairy Market

Retail Price	Const.	Unem Rate	Manf Wage	Mtls PPI	Fuel PPI	AAA Bond	Avg Age	Var Age	Skew Age	Govt. Purch. Prices Butter	Govt. Purch. Prices Cheese	Govt. Purch. Prices Nfdm	Support Prices Cl. 1	Support Prices Cl. 2	Fat CPI	Bev CPI	Meat CPI	AR(1)
Milk	3.18	.00235	.121	−.0159	.0118	−.00397	−.0962	.0136	−.0129	−.0202	−.0691	.00554	.0343	.0828	−.0411	−.00412	.0309	−.249
	(.655)[a]	(.0014)	(.0463)	(.0209)	(.0100)	(.0010)	(.0141)	(.0054)	(.0022)	(.0117)	(.0181)	(.0231)	(.0080)	(.0215)	(.0248)	(.0128)	(.0238)	(.161)
Butter	−4.31	−.00138	−.108	−.0103	−.00175	.00206	.0813	.0395	−.00238	.0925	.0527	−.0175	.0714	−.0775	.0531	−.0869	.117	.676
	(1.70)	(.0041)	(.135)	(.0645)	(.0319)	(.0033)	(.0390)	(.0160)	(.0769)	(.0346)	(.0468)	(.0604)	(.0193)	(.0596)	(.0724)	(.0353)	(.0645)	(.123)
Cheese	−3.53	−.00121	−.0585	.0613	−.00843	.00347	.102	−.00965	.0203	−.00832	−.0205	−.0433	.0677	.0893	.0690	−.0595	.0335	.610
	(3.28)	(.0079)	(.260)	(.124)	(.0607)	(.0064)	(.0747)	(.0301)	(.0145)	(.0658)	(.0908)	(.117)	(.0376)	(.115)	(.140)	(.0680)	(.125)	(.132)
Frozen	6.35	.00691	.240	−.0254	.0806	−.00008	−.114	−.0376	−.0226	.146	−.151	.206	.0155	−.138	.00427	−.0727	.139	.747
	(2.05)	(.0049)	(.163)	(.0773)	(.0387)	(.0024)	(.0472)	(.0199)	(.0295)	(.0419)	(.0557)	(.0722)	(.0228)	(.0713)	(.0869)	(.0423)	(.0769)	(.111)
Other	−.188	.00133	.0355	.0115	.0151	−.00054	.00099	.00475	−.00240	−.00094	−.0283	.00188	.0125	.0306	−.00258	.00052	−.0008	.657
	(.485)	(.0012)	(.0385)	(.0184)	(.0905)	(.0009)	(.0111)	(.0451)	(.0022)	(.00981)	(.0133)	(.0172)	(.0055)	(.0170)	(.0206)	(.0101)	(.0184)	(.126)

Regression Summary Statistics

	Milk	Butter	Cheese	Frozen	Other
R^2	.996	.990	.953	.993	.950
s[a]	.00491	.0149	.0283	.0182	.00422
DW[a]	2.02	1.55	1.80	1.60	1.76

[a] Numbers in parenthesis are standard errors; s is the standard error of the estimate; DW is the Durbin-Watson statistic.

In this set of regression results, and all others in the paper, the numbers in parentheses are estimated asymptotic standard errors of the regression coefficients, R^2 is the correlation between the observed and predicted value of the untransformed dependent variable, s is the standard error of the estimate for the regression equation, DW is the Durbin-Watson test statistic for serially correlated residuals, and u_{-j} is the regression error lagged j years.

Table 2 presents the three-stage least squares regression results for the system of five per capita demands for U.S. dairy products. Results are presented for four separate models. The complete list of instruments for the three-stage least squares estimation procedure is $\{Unem, Wage, P_{mil}, P_{fuel}, r_{bond}, Avg, Var, Skew, GP_{btr}, GP_{chs}, GP_{dm}, S_1, S_2, P_{fat}, P_{bev}, P_{meat}, Incm\}$. For the first two models in table 2, estimation is by linear three-stage least squares. For the last two models, the estimation procedure is nonlinear three-stage least squares (Jorgenson and Laffont). Three-stage least squares was used to obtain consistent estimates of the model parameters in the presence of simultaneous determination between retail prices and quantities demanded. In all of the results reported in table 2, the R^2, standard error of the estimate, and Durbin-Watson statistic for serial correlation between the error terms are calculated for the untransformed variables.

The first set of results is the linear consumer's surplus model where only the cross-price symmetry restrictions are imposed. The second set of results is the linear compensating variation model where the Slutsky symmetry conditions are imposed at the sample means. As can be seen from table 2, the problem with both of these sets of estimation results is that all of the point estimates for the income effects are positive, while only one of the own-price effects is negative. This is a serious weakness of both of these models. However, the eigenvalues for the Slutsky substitution matrices calculated at the sample means for these two models are

Linear CS Model:	−92.44	−12.56	−3.87	9.54	13.43
Linear CV Model:	−91.57	−12.59	−3.74	9.48	13.44.

Since three of the five eigenvalues are negative in both of these models, it appears that the difficulty is due to a high degree of collinearity between the dairy product price coefficients.

In an effort to test whether or not this is indeed the case, the consumer's surplus model was reestimated with the price effects matrix restricted to be symmetric, negative semidefinite. This was accomplished by a Choleski factorization, $B = -L'D^2L$, where L is an upper triangular 5×5 matrix with ones on the main diagonal and D is a diagonal 5×5 matrix. During the estimation of this model, three of the elements of D insisted on converging to zero. This results in a collinearity problem with the elements of L that are associated with the zero diagonals for D. Hence, the constraints $\delta_3^2 = \delta_4^2 = \delta_5^2 = 0.0001$ were imposed and a grid search over the values of l_{25}, l_{34}, l_{35}, and l_{45} was conducted. The values $l_{25} = 100$, $l_{34} = 0$, $l_{35} = -10$, and $l_{45} = 500$ resulted in a weighted sum of squared errors criterion, $Q(\beta) = 72.43$, with the following sensitivity to changes in these elements of L:

$l_{25} = 0$	$Q(\beta) = 73.81$	$l_{25} = 200$	$Q(\beta) = 72.42$
$l_{34} = -10$	$Q(\beta) = 72.43$	$l_{34} = 10$	$Q(\beta) = 72.43$
$l_{35} = -20$	$Q(\beta) = 72.43$	$l_{35} = 20$	$Q(\beta) = 72.43$
$l_{45} = 0$	$Q(\beta) = 72.47$	$l_{45} = 1000$	$Q(\beta) = 75.57.$

All other parameters were estimated conditional on the fixed values for δ_3, δ_4, δ_5, l_{25}, l_{34}, l_{35}, and l_{45}. The standard errors for the elements of B were derived with Slutsky's theorem, conditional on the fixed values of the locked out parameters. A joint F-test of the symmetry and concavity restrictions with thirteen degrees of freedom (10 symmetry conditions and 3 binding concavity restrictions) using the degrees of freedom corrections suggested by Laitinen, Meisner, and Judge et al. gives an F-statistic of $F(13,115) = 1.63$. The 5% critical value for the $F(13,115)$ distribution is 1.80, so that we can not reject the joint hypothesis of symmetry and negative semidefiniteness for B. The nonlinear three-stage least squares regression results are reported in the third part of table 2.

The final set of results in table 2 contains the parameter estimates and regression statistics for the weakly integrable demand model. Two additional estimation issues had to be addressed for this model. First, it follows from equation (13) that fifty-one of the fifty-five model parameters enter each of the demand equations through

the transformed income term, $\tilde{y}$. While this does not cause any difficulties from the standpoint of the asymptotic regression theory, it is important to a sample with only thirty-six observations. The reason is that the empirical model can (and will!) tend to fit one of the demand equations perfectly, which gives nonsense for results. To deal with this problem, the iterative two-stage estimation procedure discussed in LaFrance (1989, 1991) was used, in which the current set of values for $\tilde{y}$ is generated from the previous estimates of the model parameters and $\tilde{y}$ is held fixed during the current iterative round. Consistency and asymptotic normality of the convergent solution to this procedure are shown in LaFrance (1989). To deal with the joint determination of $\tilde{y}$ during estimation of the model parameters, $\tilde{y}$ was treated as one of the endogenous variables in the three-stage nonlinear least squares estimation procedure. Fortunately, the iterative process tended to converge very quickly, requiring an average of only five to six iterations to obtain convergence within five significant digits of the parameters.

The second issue regarding estimation of the integrable model results from the fact that the Slutsky substitution matrix, $S = B + \tilde{y}\gamma\gamma'$, is not constant across observations of the data. This does not represent any difficulty with respect to the symmetry of B, but it is a problem with respect to the global negative semidefiniteness of S. This difficulty was handled by imposing negative definiteness on S at the sample mean of the current estimated series for $\tilde{y}$. An alternative procedure would be to require S to be negative semidefinite at the maximum value of $\tilde{y}$, thereby ensuring that the expenditure function is concave in p at all data points.

The iterative procedure is summarized as follows. At each iterative stage of the estimation process, as $\tilde{y}$ is updated also update the fixed value for the point of strict concavity, $\tilde{y}_0$. Write the symmetric, negative definite mean Slutsky matrix, $S_0 = B + \tilde{y}_0\gamma\gamma'$, in terms of a Choleski factorization $S_0 = -L'D^2L$, where L and D are defined as before. Then solve this for the price effects matrix as $B = -(L'D^2L + \tilde{y}_0\gamma\gamma')$ and estimate the elements of L, D, and γ rather than B. For a positive $\tilde{y}_0$ (the converged value is 2389.6), this transformation shows clearly that negative definiteness of the mean Slutsky matrix is a much stronger restriction than negative semidefiniteness of the price effects matrix B.

As in the case of the concave consumer's surplus model, three of the elements of D insisted on converging to zero and the constraints $\delta_3^2 = \delta_4^2 = \delta_5^2 = 0.0001$ were imposed. A grid search over l_{23}, l_{24}, l_{25}, l_{34}, l_{35}, and l_{45} resulted in the values $l_{23} = l_{34} = l_{35} = l_{45} = 0$, $l_{24} = -5$, and $l_{25} = 80$, with a least squares criterion of $Q(\beta) = 72.19$. There was no change in the least squares criterion to four places for the following range of values in these parameters: $l_{23} = -2, 2$; $l_{24} = -10, 0$; $l_{25} = 0, 160$; $l_{34} = -30, 30$; $l_{35} = -20, 20$; and $l_{45} = -20, 20$. As in the previous case, all other parameters were estimated conditional on the fixed values for δ_3, δ_4, δ_5, l_{23}, l_{24}, l_{25}, l_{34}, l_{35}, and l_{45}. The standard errors for the elements of B were derived with Slutsky's theorem, conditional on the fixed values of the locked out parameters. A joint F-test of the symmetry and concavity restrictions with thirteen degrees of freedom gives an F-statistic of $F(13,115) = 1.62$, so that we can not reject the joint hypothesis of symmetry and negative definiteness for S_0.

One aspect of these empirical results worth emphasizing is the fact that the overall statistical properties of the weakly integrable demand model are as good as, indeed virtually indistinguishable from, those of the concave consumer's surplus model. Furthermore, there is very little degradation in the summary statistics for the integrable model relative to either of the linear approximations. Given the fact that the integrable model is consistent with economic theory and there is no compelling empirical evidence in the data leading us to reject it, my position is that, from a logical viewpoint, this is the clearly preferred alternative.

The 1950–85 average farm, wholesale, and retail dairy prices in 1989 dollars are

Support Prices	
Class 1	Class 2
21.22	15.40

Government Purchase Prices		
Butter	Cheese	Dry Milk
21.18	16.63	9.00

Retail Prices				
Milk	Butter	Cheese	Frozen	Other
1.85	3.00	3.15	3.22	0.67

The average farm milk price without price discrimination or government purchases of manufactured products is taken from LaFrance and de Gorter as \$17.59 per hundredweight (\$4.75 in 1967 dollars). The predicted wholesale and retail prices (also converted to 1989 dollars) obtained by setting both farm support prices at this

Table 2. Three-Stage Least Squares Regression Results for the U.S. Dairy Demand Model

	Const	Bev CPI	Fat CPI	Meat CPI	Avg Age	Var Age	Skew Age	Income	Retail Dairy Prices Milk	Butter	Cheese	Frozen	Other	R^2	s	DW
Linear Consumer's Surplus Model																
Milk	1832	3.97	7.29	−19.4	−36.0	−5.37	−4.27	.0299	75.7	−3.22	−16.5	−4.28	−24.7	.989	3.09	1.42
	(158)	(8.80)	(3.68)	(12.5)	(4.19)	(1.50)	(.620)	(.0081)	(41.0)	(3.76)	(5.06)	(5.01)	(16.3)			
Butter	47.1	2.71	−.490	−.282	−.401	−.529	.0350	.00011	−3.22	1.78	−11.0	3.00	3.93	.984	.235	1.73
	(16.6)	(1.00)	(.378)	(1.04)	(.476)	(.162)	(.0866)	(.0007)	(3.76)	(1.78)	(2.44)	(1.64)	(5.70)			
Cheese	−62.1	−3.39	−.0908	2.83	2.03	.673	−.241	.00146	−16.5	−11.0	5.68	−1.04	8.48	.997	.272	2.09
	(22.9)	(1.33)	(.461)	(1.16)	(.694)	(.240)	(.138)	(.0009)	(5.06)	(2.44)	(4.33)	(2.48)	(10.3)			
Frozen	28.5	2.03	−2.33	−5.43	−1.03	.317	.193	.00440	−4.28	3.00	−1.04	2.06	7.34	.979	.323	1.91
	(21.2)	(1.17)	(.517)	(1.42)	(.555)	(.199)	(.100)	(.0011)	(5.01)	(1.64)	(2.48)	(2.93)	(6.92)			
Other	225	−1.91	−.469	−1.98	−6.44	.744	−.964	.00219	−24.7	3.93	8.48	7.34	−.806	.994	.474	2.59
	(68.7)	(2.98)	(1.10)	(2.33)	(1.73)	(.603)	(.290)	(.0019)	(16.3)	(5.70)	(10.3)	(6.92)	(51.3)			
Linear Compensating Variation Model																
Milk	1832	3.85	7.26	−19.5	−36.0	−5.37	−4.27	.0301	75.9	−3.40	−16.5	−3.77	−24.7	.989	3.09	1.41
	(158)	(8.80)	(3.68)	(12.6)	(4.17)	(1.50)	(.616)	(.0031)	(41.0)	(3.77)	(5.09)	(5.07)	(16.4)			
Butter	47.1	2.71	−.491	−.281	−.400	−.528	.0352	.00010	−3.24	1.78	−11.0	3.01	3.98	.984	.235	1.73
	(16.7)	(1.00)	(.379)	(1.04)	(.475)	(.163)	(.0866)	(.0007)	(3.76)	(1.79)	(2.44)	(1.64)	(5.71)			
Cheese	−62.3	−3.39	−.0935	2.83	2.03	.674	−.240	.00146	−16.4	−11.0	5.68	−1.01	8.43	.997	.272	2.09
	(22.9)	(1.33)	(.462)	(1.16)	(.694)	(.240)	(.138)	(.0009)	(5.07)	(2.45)	(4.35)	(2.49)	(10.3)			
Frozen	28.5	2.03	−2.32	−5.43	−1.03	.317	.193	.00441	−4.24	2.98	−1.04	2.08	7.22	.979	.323	1.91
	(21.2)	(1.17)	(.518)	(1.42)	(.556)	(.199)	(.100)	(.0011)	(5.03)	(1.65)	(2.50)	(2.93)	(6.96)			
Other	226	−1.89	−.474	−1.97	−6.45	.738	−.963	.00217	−24.9	3.96	8.41	7.22	−.0322	.994	.474	2.59
	(68.8)	(2.98)	(1.10)	(2.35)	(1.73)	(.604)	(.290)	(.0019)	(16.3)	(5.71)	(10.3)	(6.93)	(51.4)			

Concave Consumer's Surplus Model																
Milk	2000	8.23	7.61	−9.35	−41.7	−4.47	−4.66	.0327	−11.5	−5.40	−8.31	1.47	8.30	.988	3.32	1.13
	(161)	(8.54)	(3.87)	(12.0)	(4.07)	(1.59)	(.654)	(.0088)	(8.87)	(2.26)	(2.74)	(1.73)	(6.60)			
Butter	79.0	.927	.218	.234	−1.29	−.320	−.196	−.00035	−5.40	−2.55	−3.85	.749	3.50	.982	.246	1.28
	(13.2)	(.681)	(.332)	(1.03)	(.329)	(.142)	(.0539)	(.0007)	(2.26)	(.888)	(.933)	(.811)	(3.01)			
Cheese	−114	−.629	−1.14	1.50	3.74	.186	.153	.00162	−8.31	−3.85	−7.07	.142	12.6	.996	.292	2.07
	(15.0)	(.861)	(.374)	(1.17)	(.413)	(.196)	(.0834)	(.0008)	(2.74)	(.933)	(2.28)	(1.47)	(6.09)			
Frozen	35.1	1.11	−1.74	−5.42	−.895	.207	.151	.00343	1.47	.749	.142	−.994	4.60	.979	.324	1.91
	(16.5)	(.851)	(.388)	(1.27)	(.421)	(.179)	(.0756)	(.0009)	(1.73)	(.811)	(1.47)	(1.13)	(3.16)			
Other	132	−2.07	1.03	−3.28	−3.88	.917	−.926	.000025	8.30	3.50	12.6	4.60	−71.6	.991	.579	1.75
	(44.0)	(2.03)	(.858)	(2.34)	(1.16)	(.436)	(.209)	(.0018)	(6.60)	(3.01)	(6.09)	(3.16)	(23.0)			
Weakly Integrable Model																
Milk	2019	8.96	7.69	−9.03	−42.2	−4.41	−4.74	.0317	−9.33	−4.26	−6.91	.803	9.47	.988	3.34	1.12
	(171)	(8.57)	(3.87)	(11.9)	(4.33)	(1.60)	(.682)	(.0871)	(5.91)	(1.95)	(2.60)	(.968)	(5.66)			
Butter	79.5	.746	.176	.0203	−1.27	−.358	−.191	−.00029	−4.26	−2.66	−4.20	.709	5.22	.981	.253	1.22
	(13.8)	(.698)	(3.28)	(1.02)	(.346)	(.133)	(.0551)	(.0007)	(1.95)	(.927)	(.660)	(.662)	(1.37)			
Cheese	−116	−.829	−1.13	1.41	3.75	.212	.144	.00178	−6.91	−4.20	−6.64	1.04	9.24	.996	.292	2.07
	(15.4)	(.826)	(.361)	(1.14)	(.424)	(.181)	(.0819)	(.0008)	(2.60)	(.660)	(1.95)	(1.05)	(3.10)			
Frozen	38.6	1.20	−1.71	−5.27	−1.08	.279	.117	.00361	.803	.709	1.04	−.395	1.67	.979	.320	1.93
	(16.6)	(.831)	(.378)	(1.20)	(.414)	(.170)	(.0709)	(.0008)	(.968)	(.662)	(1.05)	(.310)	(1.92)			
Other	133	−1.31	.931	−3.47	−3.63	.714	−.858	−.00050	9.47	5.22	9.24	1.67	−63.0	.990	.609	1.64
	(42.9)	(1.73)	(.789)	(2.34)	(.977)	(.379)	(.145)	(.0016)	(5.66)	(1.37)	(3.10)	(1.92)	(25.0)			

level and the other variables at their sample means are

Predicted Wholesale Prices

Butter	Cheese	Dry Milk
26.37	18.74	9.37

Predicted Retail Prices

Milk	Butter	Cheese	Frozen	Other
1.70	2.74	2.96	3.00	0.67

These are the relative price changes that are used to construct our comparison of the welfare measures discussed in the previous section. All other variables on the right-hand sides of the demand equations are set at their sample means for the comparison.

The average income transfer away from consumers is the sum of the price difference for each good times the historical average quantity demanded. In millions of 1989 dollars, this figure is $10,108. The welfare measures for the price changes from the historical average to the predicted levels, in millions of 1989 dollars, are as follows:

	Linear CS	*Linear CV*
Welfare measure	10,117	10,102
Deadweight loss	8.73	−95.80

	Concave CS	Integrable
Welfare measure	10,165	10,158
Deadweight loss	56.61	49.99

Over 99% of each of the welfare measures is income transfer. This transfer is common to all of the four measures by construction. Thus, it is not surprising that all of the welfare measures are within one percent of each other. But this is precisely why Hausman's critique is so important in empirical welfare analysis. It is the relative size of the change in consumer welfare net of any income transfers that matters in cost-benefit analysis. And this is where the approximations can not stand up to the test. The linear consumer's surplus measure is 82.5% less than the compensating variation measure. The linear compensating variation measure has the wrong sign, undoubtedly because the linearized estimates do not impose the proper curvature on the data. Even the concave consumer's surplus measure overstates the exact compensating variation by 15%.

Conclusion

The concave consumer's surplus model is as difficult to estimate as the integrable model, yet it does not have any direct interpretation in terms of consumer behavior. I can see no reason to perform applied welfare analysis in a manner that is not logically consistent. The ad hoc, short-cut method of linear consumer's surplus gives siginificantly different answers for deadweight loss than either concave consumer's surplus or exact welfare procedures. The imposition of concavity requirements on the consumer's surplus approach makes that procedure as onerous as exact welfare estimation and lacks the satisfaction of being logically and theoretically correct. So, why not do it right?

References

Belsley, D. A. *Conditioning Diagnostics*. New York: John Wiley & Sons, 1991.

Belsley, D. A., E. Kuh, and R. E. Welsh. *Regression Diagnostics*. New York: John Wiley & Sons, 1980.

Burt, O., and D. Brewer, "Estimation of Net Social Benefits from Outdoor Recreation." *Econometrica* 39(1971):813–27.

Chavas, J.-P. "Structural Change in the Demand for Meat." *Amer. J. Agr. Econ.* 65(1983):148–53.

Chiccetti, C., A. Fisher, and V. K. Smith. "An Econometric Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy." *Econometrica* 44(1976):1259–76.

Freebairn, J., and G. Rausser. "Effects of Changes in the Level of U.S. Beef Imports." *Amer. J. Agr. Econ.* 57(1975):676–88.

Huang, K., and R. Haidacher. "Estimation of a Composite Food Demand System for the United States." *J. Bus. and Econ. Statis.* 1(1983):285–91.

Jorgenson, D. W., and J. Laffont. "Efficient Estimation of Nonlinear Simultaneous Equations with Additive Disturbances." *Ann. Econ. and Soc. Measure.* 3(1974):615–40.

Judge, G. G., W. E. Griffiths, R. C. Hill, H. Lutkepohl, and T-C. Lee. *The Theory and Practice of Econometrics*, 2nd ed., New York: John Wiley & Sons, 1985.

LaFrance, J. "Incomplete Demand Systems and Semilogarithmic Demand Models." *Aust. J. Agr. Econ.* 34(1990):118–31.

——. "Linear Demand Functions in Theory and Practice." *J. Econ. Theory* 37(1985):147–66.

——. "The Structure of Constant Elasticity Demand Models." *Amer. J. Agr. Econ.* 68(1986):543–52.

——. "Weak Separability and Two-Stage Budgeting: Problems of Estimation and Welfare Measurement." Paper presented at the Australasian meeting of the Econometric Society, University of New England, Armidale, Australia, 1989.

——. "When Is Expenditure 'Exogenous' in Separable Demand Models?" *West. J. Agr. Econ.* 16(1991):49–62.

LaFrance, J., and H. de Gorter. "Regulation in a Dynamic Market: The U.S. Dairy Industry." *Amer. J. Agr. Econ.* 67(1985):821–32.

LaFrance, J., and W. M. Hanemann. "The Dual Structure of Incomplete Demand Systems." *Amer. J. Agr. Econ.* 71(1989):262–74.

Laitinen, K. "Why Is Demand Homogeneity So Often Rejected?" *Econ. Letters* 1(1978):187–91.

Meisner, J. F. "The Sad Fate of the Asymptotic Slutsky Asymmetry Test for Large Systems." *Econ. Letters* 2(1979):231–33.

Safyurtlu, A., S. Johnson, and Z. Hassan. "Recent Evidence on Market Demand Systems for Food in Canada." *Can. J. Agr. Econ.* 34(1986):475–93.

Willig, R. "Consumer's Surplus Without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Applied General Equilibrium Welfare Analysis

Walter N. Thurman

Interventions into markets have spillover effects. For example, when a price is supported in one market, equilibrium prices in related markets change. When price changes spill over, the welfare effects of interventions spill over as well. It is a common problem in applied welfare economics to account for such effects.

Harberger has long advocated a particular technique for measuring the sum of all effects of an intervention, both in the intervened-in and related markets. The technique is to calculate consumer and producer surplus changes behind demand and supply curves that are explicitly general equilibrium (GE). That is, along curves that hold constant demand and supply conditions in related markets but not prices. By calculating surplus changes with respect to such curves, one simulates the equilibrium price paths in other markets resulting from the intervention and captures the sum of the welfare effects.

Several authors have elaborated on Harberger's theme and developed further the craft of GE welfare measurement. Included among these, and in chronological order, are Schmalensee (1971, 1976), Wisecarver, Anderson, Panzar and Willig, and Carlton. These authors establish the welfare significance of GE surplus changes for special cases. It was the work of Just, Hueth, and Schmitz (appendix D) and Just and Hueth that developed in full generality the meaning of general equilibrium surplus changes.

A sizeable and growing agricultural and resource economics literature has addressed applied welfare economics problems in a general equilibrium way. Empirical articles citing Just, Hueth and Schmitz or Just and Hueth as an authority for GE welfare results include: Crutchfield on demand for fish, Foster et al. on water subsidies, Gardner on the political economy of commodity programs, Lemieux and Wohlgenant on biotechnology, Leu, Schmitz, and Knudson, and Lopez on U.S. sugar policy, Mullen and Menz on lake acidification, and Thurman and Easley on commercial fishery catch restrictions. A smaller and independent literature uses GE welfare results to interpret travel cost methods in natural resource economics. See Bockstael and McConnell, Kling, and Smith.

With the current and increasing interest in applying GE welfare measurements, it seems useful to review what is known and to discuss some of the issues applied researchers must face. The first half of this paper demonstrates, through example, the variety of circumstances in which GE welfare analysis works. The second half explores the limits of its generality.

The Welfare Significance of General Equilibrium Curves

Derived Demand with Fixed Proportions

The analysis begins with a restrictive, but instructive, model of derived demand that is found in Marshall. A more modern treatment is found in Friedman. He describes a competitive knife industry that combines blades and handles using a fixed-proportions technology. Competition in the handle, blade, and knife markets ensures that, in equilibrium, the price of a (one-bladed) knife will equal the price of a blade plus the price of a handle. This condition becomes a derived demand for blades when one takes as given the supply of handles and the demand for knives. Figure 1 shows the derived demand for blades, D_B, as the vertical difference between the demand for knives, D_K, and the supply of handles, S_H. D_B is a GE derived demand because P_H and P_K vary along it so as to maintain equilibrium in their markets.

Suppose that the supply of blades (not shown) intersects D_B at the point (P_B^o, Q^o). The equilibrium quantity of knives, handles, and blades is Q^o. The equilibrium prices are P_B^o, P_H^o, and P_K^o. Next, suppose that a government policy or

Walter N. Thurman is a faculty member in the Department of Agricultural and Resource Economics, North Carolina State University.

The author thanks J. E. Easley, John Mullen, and Randy Rucker for helpful comments on an earlier draft.

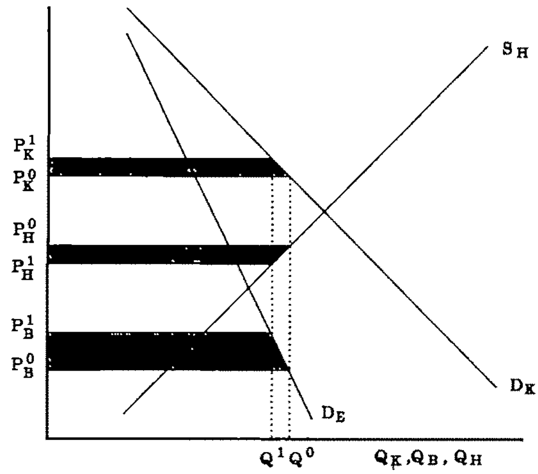


Figure 1. The derived demand for blades

a supply shift raises the price of blades to P_B^1. The lower equilibrium quantity raises the price for knives to P_K^1 and lowers the price of handles to P_H^1.

The natural measure of welfare loss resulting from the price rise is the change in consumer surplus behind D_B. The natural measure is also an appropriately aggregate measure. Because D_B combines consumer knife demand and handle supply, the D_B-surplus change measures the surplus losses to the two groups; the bottom trapezoid equals the sum of the top trapezoid (the loss in consumer surplus from the P_K increase) and the middle trapezoid (the loss in handle suppliers' surplus from the P_H decrease). As discussed in Alston, the truth of the proposition can be seen geometrically from the construction of the derived demand curve. To set the stage for more general situations, a calculus proof follows.

The change in D_B-surplus is

$$\Delta CS_B = -\int_{P_B^0}^{P_B^1} D_B(P_B)dP_B.$$

The movement along D_B describes an equilibrium relationship between Q and P_B. Using the relationship to change variables of integration from P_B to Q gives

$$\Delta CS_B = -\int_{Q^0}^{Q^1} Q\frac{dP_B}{dQ}dQ.$$

The equilibrium condition that $P_B = P_K - P_H$ implies that

$$\frac{dP_B}{dQ} = \frac{dP_K}{dQ} - \frac{dP_H}{dQ},$$

which, in turn, implies that

$$\Delta CS_B = -\int_{Q^0}^{Q^1} Q\left(\frac{dP_K}{dQ} - \frac{dP_H}{dQ}\right)dQ$$
$$= -\int_{Q^0}^{Q^1} Q\frac{dP_K}{dQ}dQ + \int_{Q^0}^{Q^1} Q\frac{dP_H}{dQ}dQ.$$

Changing variables from Q to P_K in the first integral and from Q to P_H in the second gives

$$\Delta CS_B = -\int_{P_K^0}^{P_K^1} D_K(P_K)dP_K + \int_{P_H^0}^{P_H^1} S_H(P_H)dP_H$$
$$= \Delta CS_K + \Delta PS_H.$$

This is the welfare result: the change in D_B-surplus equals the change in knife consumers' surplus plus the change in handle suppliers' surplus. All surplus changes are negative in this instance. The connection between the surplus change and compensation measures is as follows. If D_K is the compensated demand curve corresponding to the initial utility level, then ΔCS_K is the compensating variation to knife consumers. ΔPS_H is the change in quasi-rents to producers of handles and their input suppliers. (See Just, Hueth, and Schmitz, appendix B, and Just and Hueth.)

The More General Case of Derived Demand

Consider next the case of general substitution in production in a competitive industry with a fixed number of identical firms. As in the previous case, the surplus change behind a GE derived demand curve measures welfare changes in all related markets.

The graphical analysis is shown in figure 2. Two inputs, x_1 and x_2, are substitutes used to produce Q. The initial equilibrium prices are (w_1^o, w_2^o, p^o). A policy exogenously increases the price of x_1 from w_1^o to w_1^1. As well as affecting the quantity of x_1 demanded, the increase in w_1 shifts the demand for x_2 and the supply of Q. As D_2 and S shift, the equilibrium w_2 and p will change.

The equilibrium effect on p is unambiguous: an increase in an input's price can only increase the price of output. (However, Panzar and Willig point out that this depends upon the identical firms assumption.) The effect on w_2 is not clear. There are substitution effects (w_1 has risen) and output effects (Q has fallen) and either could

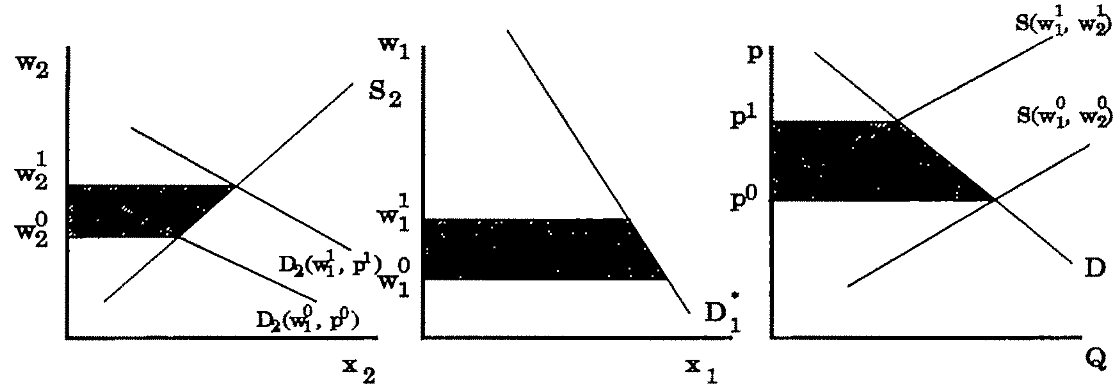


Figure 2. General equilibrium derived demand

dominate (see Hicks). In figure 2, the substitution effect is assumed to dominate and, in net, the demand for x_2 increases and so w_2 increases. The final equilibrium is (w_1^1, w_2^1, p^1) which reflects a loss in consumer surplus in the output market, a gain in quasi-rents to x_2 suppliers, and a loss in Q-producer profits. There also are effects on x_1 suppliers which must be considered separately.

Prices move along equilibrium paths in figure 2. In the x_2 and Q markets, the initial and final points are characterized by the intersection of supply and demand curves conditional on equilibrium prices in other markets. In the x_1 market, the D_1^* locus is defined as the quantity of x_1 demanded for any given w_1 assuming that the x_2 and Q markets clear. As w_1 exogenously changes along D_1^*, w_2 and p adjust to maintain equilibrium. Thus, D_1^* is the GE derived demand for x_1. The welfare significance of D_1^* is that the change in surplus behind it equals the loss in consumer surplus in the output market minus the gain in quasi-rents to x_2 suppliers plus the loss in profits to Q producers. A proof of this statement follows for the more general case of n inputs.

The industry profit function is the sum of the profit functions of the identical firms in the industry. Write the industry profit function as $\Pi(p,w)$, where p is output price and w is a vector of n input prices. Any change in prices can be linked to the change in industry profits through Hotelling's lemma:

$$(1)\quad d\Pi = \Pi_p dp + \sum_{k=1}^{n} \Pi_k dw_k = S(p,w)dp - \sum_{k=1}^{n} D_k(p,w)dw_k,$$

where $\Pi_p \equiv \partial\Pi/\partial p$ and $\Pi_k \equiv \partial\Pi/\partial w_k$.

In equilibrium, the changes in p and the w_k's depend upon the exogenous change in w_1. Denote the equilibrium relationships as $p(w_1)$ and $w_k(w_1)$ for $k = 2, \ldots, n$. Substituting the equilibrium relationships and their differentials into (1) gives the change in profits caused by the change in w_1:

$$\Delta\Pi = \int_{w_1^0}^{w_1^1} \frac{d\Pi}{dw_1} dw_1 = \int_{w_1^0}^{w_1^1} \left\{ S[p(w_1), w(w_1)] \frac{dp}{dw_1} - D_1[p(w_1), w(w_1)] - \sum_{k=2}^{n} D_k[p(w_1), w(w_1)] \frac{dw_2}{dw_1} \right\} dw_1,$$

where $w(w_1) = [w_1, w_2(w_1), \ldots, w_n(w_1)]'$.

By changing variables of integration, the profit change is related to individual market surplus changes:

$$(2)\quad \Delta\Pi = \int_{p^0}^{p^1} S[p,w(p)]dp - \int_{w_1^0}^{w_1^1} D_1[p(w_1), w(w_1)]dw_1 - \sum_{k=2}^{n} \int_{w_k^0}^{w_k^1} D_k[p(w_k), w(w_k)]dw_k,$$

where the equilibrium relationships have been inverted in the transformation of variables.

The final step is to observe that the equilibrium relationships maintain equilibrium in all markets in the integrals of equation (2). The equilibrium equalities of demand and supply and the definition of D_1^* allow the change in profits

to be written as

$$\Delta\Pi = \int_{p_1^0}^{p_1^1} D(p)dp - \int_{w_1^0}^{w_1^1} D_1^*(w_1)dw_1 - \sum_{k=2}^{n} \int_{w_k^0}^{w_k^1} S_k(w_k)dw_k$$

$$= -\Delta CS + \Delta CS_1^* - \sum_{k=2}^{n} \Delta\Pi_k,$$

where $\Delta\Pi_k$ is the change in profits, or quasi-rents, in market k. The last equality gives the welfare significance of D_1^*:

$$\Delta CS_1^* = \Delta CS + \sum_{k=2}^{n} \Delta\Pi_k + \Delta\Pi, \tag{3}$$

where ΔCS_1^* is the algebraic sum of surplus changes to all groups affected by the price change.

This result is easily modified to the long-run situation of unrestricted entry of identical firms. In that case, profits are zero before and after the change in w_1 and so $\Delta\Pi = 0$. Equation (3) holds with that modification. Panzar and Willig show that (3) also holds for the case of entry by heterogenous firms. In that case $\Delta\Pi$ represents the sum of changes in rents to inframarginal firms.

Consumer GE Demands

The discussion of derived demand took as a primitive concept the consumer demand curve and the surplus change behind it. However, if consumer demand is shifted by other-market prices that are themselves affected by the policy examined, then there is a general equilibrium version of consumer demand. We will see that the GE consumer demand represents the welfare of all participants in the other markets.

Consider the example in Thurman of two goods that are substitutes in demand and sold in competitive markets. A per-unit tax is placed on the first good, driving a wedge between demand and supply price. The increase in the price of the taxed good shifts out the demand for its substitute, thereby increasing the substitute's price and, in turn, shifting out the demand for the taxed good. The effects of the tax are shown in figure 3 where $D_1(P_2^o)$ and $D_2(P_1^o)$ are the compensated demands for Q_1 and Q_2 conditional on the initial equilibrium prices P_1^o and P_2^o. The per unit tax of τ causes a new equilibrium pair of demand prices, P_1^1 and P_2^1, and a new supply price of $\tilde{P}_1^1$. The demands for both goods shift out from the demand price increases. Here, unlike in the previous examples, the price change is endogenous while the exogenous parameter is the tax rate.

The welfare effects of the tax fall on consumers, who suffer increases in the prices of both goods, on Q_1 producers who suffer a decrease in P_1, and on Q_2 producers who benefit from an increase in P_2. The Q_1 producers' loss in profits is their loss in producer surplus (see Just, Hueth, and Schmitz, chap. 4) which equals $(A + B)$. Q_2 producers gain $(C + D)$. The consumers' losses are more complicated due to the fact that demand curves in both markets shift to the right.

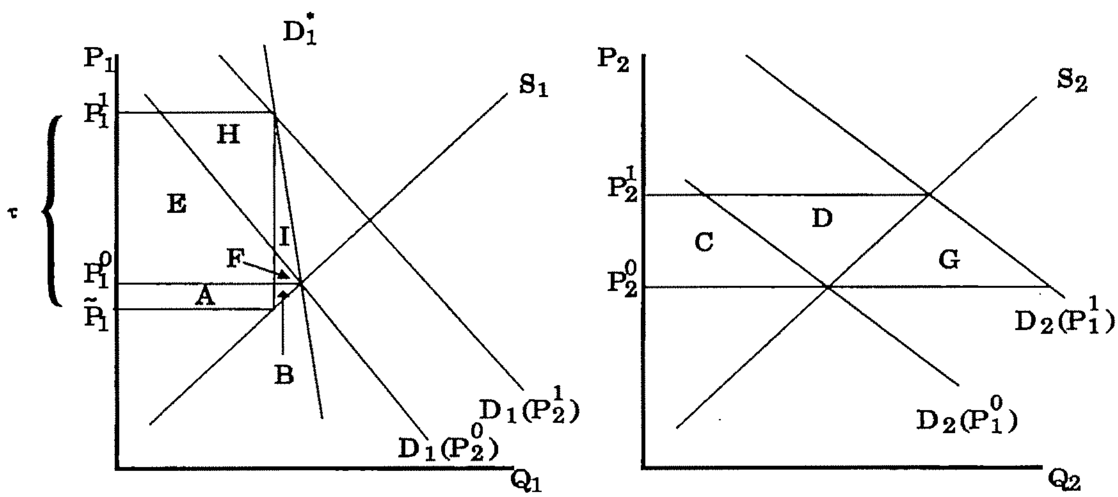


Figure 3. General equilibrium consumer demand

Thurman shows that if all demands are compensated then the compensating variation is $(E + F) + (C + D + G)$.

Now consider a measure of welfare loss based on D_1^*, the general equilibrium demand for Q_1. P_2 varies continuously along D_1^* so as to maintain equilibrium in the Q_2 market for each P_1. It turns out (see Thurman) that the change in surplus behind D_1^* captures not only the consumer surplus change in the Q_1 market but the net surplus loss, consumer and producer, in the Q_2 market as well. Specifically,

$$|\Delta CS_1^*| = CV - \Delta \Pi_2,$$

where ΔCS_1^* is the (negative) general equilibrium change in consumer surplus measured in the taxed market, CV is the (positive) compensating variation to consumers for the pair of price increases, and $\Delta \Pi_2$ is the (positive) change in producer profits in the second market. The welfare triangle $B + F + I$ is the total welfare loss net of tax revenue.

Limitations and Qualifications to the Application of GE Welfare Measures

The Relevance of Compensation

Consider again the example of figure 3. It was argued that if one calculates the surplus change with respect to the GE demand curve, then one captures both the consumer loss due to increases in P_1 and P_2 and the gain to suppliers of Q_2. But the argument was based on a compensated GE demand curve. How relevant is this measure when compensation does not take place?

The question can be asked of any compensating variation measure, GE or not. In a single-market context, the compensating variation is a potential Pareto improvement criterion: If society were to compensate losers and winners from the tax, how much would the compensation cost? It does not necessarily measure the utility loss to losers or gain to winners if the compensation does not take place.

Harberger (1971) has defended the potential Pareto improvement criterion as a means of distinguishing the efficiency effects of policies from their distributional effects. His prescription is: first measure the shrinkage in the public pie caused by the policy (the compensating variation), then identify the changes in income distribution generated by the policy. It is on these grounds that Harberger and others have defended the hypothetical, as-if-compensated, consumer surplus measures. The same argument can be applied to the compensating variation (Hicksian consumer surplus) measures discussed here.

However, with GE measures there is another sense in which the calculation is counterfactual. In the discussion of figure 3, the increases in P_1 and P_2 assumed compensation of consumers. In particular, equilibrium in the Q_2 market was maintained along a compensated, Hicksian, demand curve. If, in fact, consumers were not compensated the equilibrium price path would be different. The D_1^*-surplus change measures the hypothetical compensation required for a hypothetical pair of price increases that would occur only if consumers were compensated.

How does the doubly hypothetical measure relate to the compensating variation for the actual (without compensation) changes in prices? Consider this question for an exogenous increase in P_1 from P_1^o to P_1^1 (rather than an exogenous tax), a slight simplification of figure 3.

Let $D_1(P_1, P_2, U)$ and $D_2(P_1, P_2, U)$ denote the representative consumer's compensated demand curves. Let $X_1(P_1, P_2, Y)$ and $X_2(P_1, P_2, Y)$ denote the Marshallian demand curves. Let $S_2(P_2)$ denote the supply curve of Q_2. If consumers are compensated, then the equilibrium path of P_2 is described implicitly by

$$D_2(P_1, P_2, U) = S_2(P_2). \tag{4}$$

The explicit Hicksian P_2 path is the solution to (4) for a given P_1 and U denoted $P_2^H(P_1, U)$. If consumers are not compensated, the Q_2-market equilibrium is described by

$$X_2(P_1, P_2, Y) = S_2(P_2).$$

The implied Marshallian path is denoted $P_2^M(P_1, Y)$.

If both Q_1 and Q_2 are normal goods then, as P_1^o rises to P_1^1, P_2^H rises faster than P_2^M because income is higher along the Hicksian path. Denote the final price in the Q_2 market along the Hicksian path as P_2^1. It is higher than the final price along the Marshallian path, denoted $\tilde{P}_2$.

Now consider the two welfare measures. The first can be called the behavior-consistent compensation. It is the as-of-compensated measure already discussed. It is called behavior consistent because it assumes that consumer behavior is consistent with the compensation being calculated. Denote the GE behavior-consistent measure the same as before: ΔCS_1^*.

The second welfare measure is called the facts-consistent measure. It measures and sums the compensating variations to all parties affected

by the policy but measures how much is required to compensate for the price changes that would occur should compensation not be made. Denote the facts-consistent measure $\Delta\tilde{W}$. It is called facts consistent because the price path conforms to the nearly universal situation of no explicit compensation to affected parties.

The two measures are relevant in different circumstances. As Harberger argues, the behavior-consistent measure is the reduction in wealth to the economy as a whole. It is of no consequence that the other-market prices compensated for are hypothetical; if one is interested in the economy-wide compensation required for the exogenous policy, the behavior-consistent measure is the proper measure. It is the efficiency cost to the representative agent and is relevant to social benefit-cost analysis.

However, the behavior-consistent measure does not disaggregate. If the conceptual experiment of interest is to adopt the policy without compensation, and if one wishes to analyze the effects on various groups, then the facts-consistent measure is appropriate. This is the context of political economy analysis of government programs, an increasingly common use for empirical welfare measures (see Gardner; Babcock, Carter, and Schmitz; Rucker and Thurman). In such analyses, policy-induced welfare changes to different groups are used to explain the political support for and existence of government programs. For these purposes, the facts-consistent measure is relevant. The questions here involve not changes in the size of the aggregate pie, as the behavior-consistent approach measures, but sums of changes in the sizes of several group pies.

Consider, then, the relationship between ΔCS_1^* and $\Delta\tilde{W}$. ΔCS_1^* adds together the (positive) compensation for consumers facing the pair of price rises from (P_1^o, P_2^o) to (P_1^1, P_2^1) and the (negative) compensation to Q_2 producers for the price rise from P_2^o to P_2^1; $\Delta\tilde{W}$ adds together the smaller compensation to consumers for the price rises from (P_1^o, P_2^o) to $(P_1^1, \tilde{P}_2)$ and the smaller (negative) compensation to Q_2 producers for the price rise from P_2^o to $\tilde{P}_2$.

The difference between the two measures can be written as

$$(5)\quad \Delta CS_1^* - \Delta\tilde{W} = [m(P_1^1, P_2^1, U^o) - m(P_1^1, \tilde{P}_2, U^o) - [\Pi_2(P_2^1) - \Pi_2(\tilde{P}_2)] = \int_{\tilde{P}_2}^{P_2^1} [D_2(P_1^1, P_2, U^o) - S_2(P_2)]dP_2.$$

By definition of the compensated equilibrium, $D_2(P_1^1, P_2^1, U^o) = S_2(P_2^1)$. Therefore, for any P_2 less than P_2^1, the compensated quantity demanded exceeds the quantity supplied and the integrand in (5) is positive. Therefore, $\Delta CS_1^* > \Delta\tilde{W}$.

Figure 4 illustrates the fact that ΔCS_1^* must be larger than $\Delta\tilde{W}$. The extent of the difference, the integral in (5), is shown as the shaded triangle. If Q_2 were an inferior good, P_2^1 would be lower than $\tilde{P}_2$. But (5) would still be positive and ΔCS_1^* would exceed $\Delta\tilde{W}$. I do not know how general this result is.

One would like to know how small the difference between the two measures is. Evidence that the difference between the two measures can be significant comes from a simple simulation. The simulation model represents the two markets in figure 3. The representative consumer's utility function is

$$U(Q_1, Q_2) = Q_1^{\gamma} Q_2^{1-\gamma}.$$

And Q_2 supply is

$$S_2(P_2) = P_2^{\epsilon}.$$

The two welfare measures are calculated for an exogenous $(100\tau)\%$ increase in P_1. The percentage difference between the behavior-consistent (ΔCS_1^*) and facts-consistent ($\Delta\tilde{W}$) measures can be shown to be

$$\frac{\Delta CS_1^* - \Delta\tilde{W}}{\Delta\tilde{W}} = \frac{\left[(1+\tau)^{\frac{\gamma(\epsilon+1)}{\epsilon+\gamma}} - 1\right]\left(\frac{\epsilon+\gamma}{\epsilon+1}\right)}{(1+\tau)^{\gamma} - 1} - 1.$$

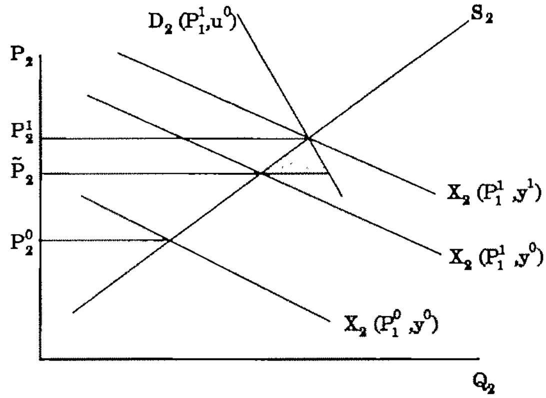


Figure 4. Compensated and uncompensated equilibria

Calculations of the discrepancy for different values of γ and τ are displayed in figure 5. Figure 5 shows how the discrepancy varies with the tax rate if the elasticity of Q_2 supply is .1 and for three different values of γ. The top curve there shows that if $\gamma = .1$ the discrepancy between the two measures for a 10% tax is about 2%. For a 50% tax, the discrepancy rises to 10%. The discrepancies are similar for a γ of .5 and are lower for a γ value of .9. Other simulations show that larger values of ϵ, the Q_2 supply elasticity, makes the discrepancies smaller than shown in figure 5. Evidently, this is because the Q_2-market compensated and uncompensated equilibria have nearly the same prices when ϵ is large.

The simulation is informative, despite the simplicity of the model, because it illustrates how the difference between the facts-consistent and behavior-consistent measures can be either trivial or significant depending upon market parameters. Apparently, one should not be cavalier in identifying one with the other.

While empirical GE welfare studies do not discuss this issue (Just, Hueth, and Schmitz do on p. 194) measured GE surplus changes are usually interpreted as the behavior-consistent measure. Consumer income typically is deflated by a price index and the resulting demand interpreted as holding real income, hence utility, constant. Thus, the estimated GE curve is more like a Hicksian than a Marshallian relation. (However, Wohlgenant criticizes this interpretation as being strictly true only for homothetic preferences.) To the extent that empirical measures are more like ΔCS_1^* than $\Delta \bar{W}$, they do not add up the compensating variations of actual price changes to affected groups. They do measure, as Harberger claims, the reduction in wealth to the economy as a whole resulting from a policy.

Distortions in Other Markets

A second, and well-known, obstacle to GE single-market welfare analysis is the presence of distortions in other markets. Harberger (1964, 1971) emphasizes that GE surpluses measured in one market will not include the proper accounting of other-market welfare changes if distortions exist in the other markets. Just, Hueth,

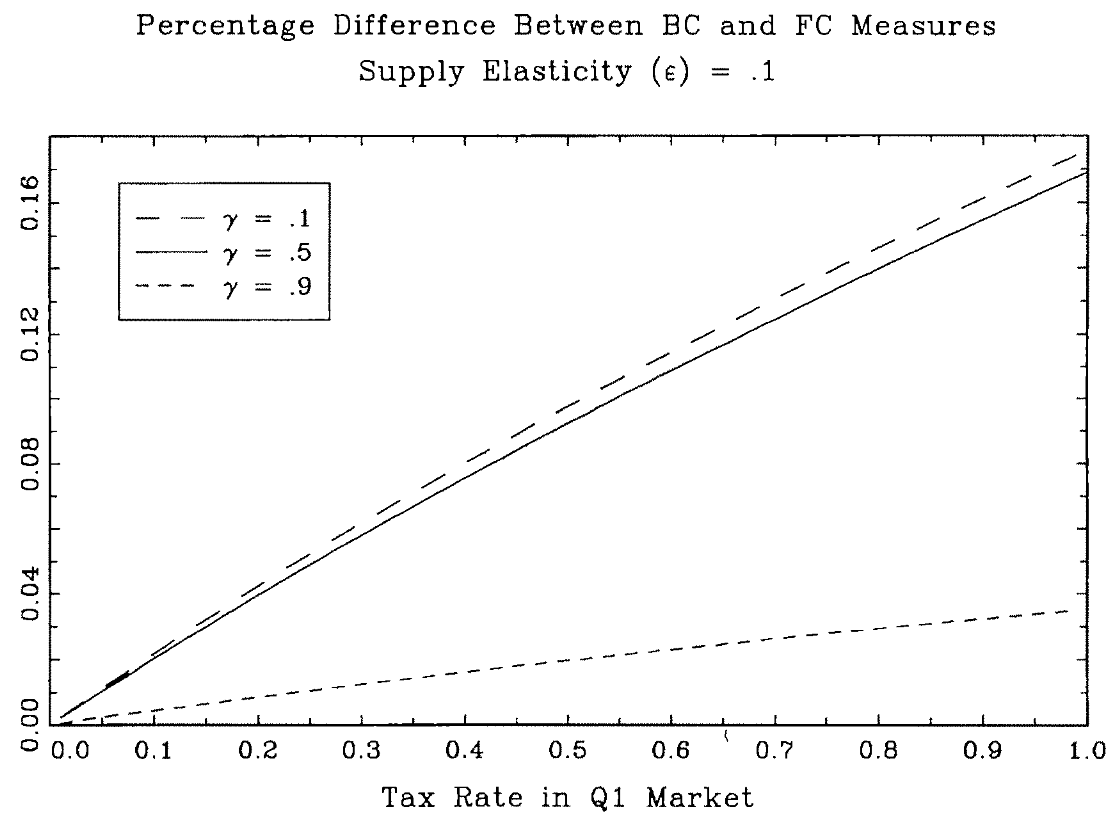


Figure 5. Simulation of the difference between the facts-consistent and behavior-consistent measures

and Schmitz discuss this issue in chapter 9, pp. 196–99 and in appendix D. Intuitively, GE welfare measurement works in the undistorted case because prices in other markets represent marginal values to all parties. When a tax is imposed and other-market prices move along equilibrium paths, the marginal values are counted along the GE curve. When a distortion already exists in one of the other markets, price does not reflect marginal value to everyone. If, for example, demand price exceeds supply price, then there are net social gains from increasing consumption and net social losses from reducing consumption. These gains or losses are not registered along the GE curve in the taxed market.

Multiple Sources of Feedback

A third problem with the application of GE welfare analysis arises in the case of multiple paths of equilibrium feedback. The issues are discussed in Thurman. To illustrate the problem, return to the example in figure 3 of two goods that are substitutes in demand. A GE surplus measure in the Q_1 market measures the welfare loss of a tax to consumers of both goods and to producers of Q_2. A symmetric result holds when Q_1 and Q_2 are substitutes in supply but not in demand: the surplus change behind a GE supply curve in the Q_1 market measures the change in profits to producers of the two goods as well as the welfare loss to consumers in the Q_2 market. Problems arise when Q_1 and Q_2 are related both in production and in consumption.

Figure 6 shows a specific tax placed on Q_1 that raises demand price and lowers supply price in the Q_1 market. Because Q_1 and Q_2 are both demand and supply substitutes, the changes in prices in the Q_1 market shift both S_2 and D_2 to the right resulting in an indeterminate change in P_2. Figure 6 shows P_2 rising. The post-tax equilibrium is described by a price of P_2^1 in the second market and the pair of prices $(P_1^1, \tilde{P}_1^1)$ in the first market. S_1^* and D_1^* are the GE loci of points for producer and consumer equilibrium for different levels of the tax.

In Thurman it is proved that S_1^* and D_1^* have welfare significance but not that which one might anticipate. Specifically, the welfare triangle constructed from S_1^* and D_1^* measures the economy-wide welfare loss from the tax net of government revenue. However, neither the GE consumer surplus loss nor GE producer surplus loss alone measures any meaningful aggregate of welfare effects. In this case, a partial analysis based on only S_1^* or D_1^* would have no meaning.

The reason for this result is that, in general, surplus changes along GE curves add together welfare changes in the intervened-in market and integrals along equilibrium paths in other markets. In the case of figure 3, only D_2 shifts and the other-market equilibrium path reflects something welfare-meaningful: a producer surplus change. In the case of figure 6, the equilibrium path in the Q_2 market is neither a producer nor consumer surplus change because both supply and demand are shifting. Therefore, the consumer surplus change behind D_1^* measures something with no welfare relevance. But, it turns out, S_1^* captures the same equilibrium area in the Q_2 market (and with a negative sign) so that adding together the surplus changes behind S_1^* and D_1^* cancels out the meaningless area. One is left with the proper economy-wide measure.

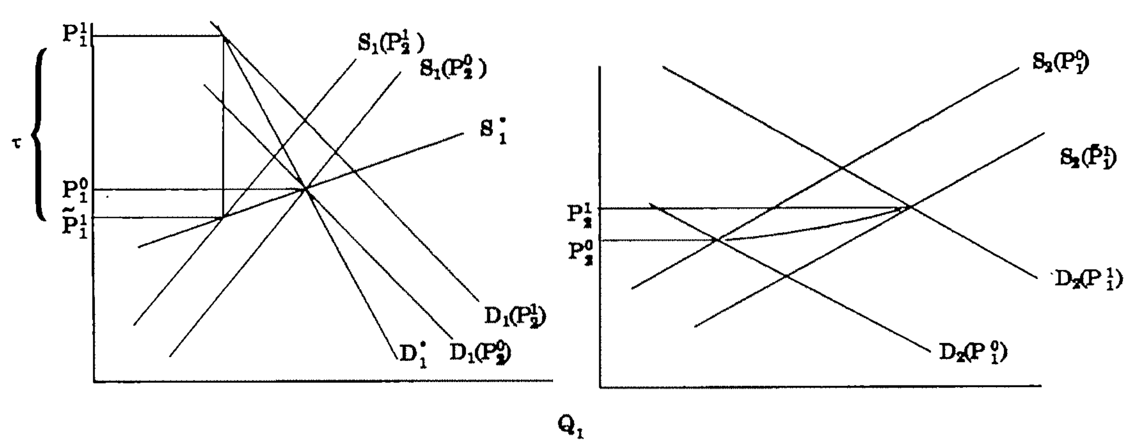


Figure 6. Multiple sources of feedback

Conclusion

One motivation for GE welfare analysis is that it economizes on data collection. In some applications, no data need be collected from markets other than the one affected by policy. While this economy can be real, there is another reason to think that GE welfare measurement is useful. Data that are readily available will tend to be used and a resulting empirical supply or demand curve will be some combination of a partial equilibrium and a general equilibrium relationship. The contribution of GE welfare analysis in this instance is to help one interpret surplus areas behind such curves; to help one determine whose welfare is and is not represented.

References

Alston, Julian. "Research Benefits in a Multimarket Setting." International Service for National Agricultural Research-Australian Centre for International Agricultural Research, Work. Pap. No. 18, July 1990.

Anderson, James E. "The Social Cost of Input Distortions: A Comment and a Generalization." *Amer. Econ. Rev.* 66(1976):235–38.

Babcock, Bruce A., Colin A. Carter, and Andrew Schmitz. "The Political Economy of U.S. Wheat Legislation." *Econ. Inquiry* 28(1990):333–53.

Bockstael, Nancy E., and Kenneth E. McConnell. "Welfare Measurement in the Household Production Framework." *Amer. Econ. Rev.* 73(1983):806–14.

Carlton, Dennis W. "Valuing Market Benefits and Costs in Related Output and Input Markets." *Amer. Econ. Rev.* 69(1979):688–96.

Crutchfield, Stephen R. "Estimation of Foreign Willingness-to-Pay for United States Fishery Resources: Japanese Demand for Alaska Pollock." *Land Econ.* 59(1982):16–22.

Foster, William E., Linda S. Calvin, Grace M. Johns, and Patricia Rottschaefer. "Distributional Welfare Implications of an Irrigation Water Subsidy." *Amer. J. Agr. Econ.* 68(1986):778–86.

Friedman, Milton. *Price Theory*. Chicago: Aldine Publishing Co., 1976.

Gardner, Bruce. "Causes of U.S. Farm Commodity Programs." *J. Polit. Econ.* 95(1987):290–310.

Harberger, Arnold C. "The Measurement of Waste." *Amer. Econ. Rev.* 54(1964):58–76.

——. "Three Basic Postulates of Applied Welfare Economics: An Interpretive Essay." *J. Econ. Lit.* 9(1971):785–97.

Hicks, J. R. *The Theory of Wages*. Gloucester MA: Peter Smith, 1957.

Just, Richard E., and Darrell L. Hueth. "Multimarket Welfare Measurement." *Amer. Econ. Rev.* 69(1979):947–54.

Just, Richard E., Darrell L. Hueth, and Andrew Schmitz. *Applied Welfare Economics and Public Policy*. Englewood Cliffs NJ: Prentice-Hall, 1982.

Kling, Catherine L. "A Note on the Welfare Effects of Omitting Substitute Prices and Qualities from Travel Cost Models." *Land Econ.* 65(1989):290–96.

Lemieux, Catharine, and Michael K. Wohlgenant. "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin." *Amer. J. Agr. Econ.* 71(1989):903–14.

Leu, Gwo-Jiun M., Andrew Schmitz, and Ronald D. Knutson. "Gains and Losses of Sugar Program Policy Options." *Amer. J. Agr. Econ.* 69(1987):591–602.

Lopez, Rigoberto. "Political Economy of U.S. Sugar Policies." *Amer. J. Agr. Econ.* 71(1989):20–31.

Marshall, Alfred. *Principles of Economics*, 8th ed. London: reprinted by Macmillan and Co., 1920.

Mullen, John K., and Fredric C. Menz. "The Effect of Acidification Damages on the Economic Value of the Adirondack Fishery to New York Anglers." *Amer. J. Agr. Econ.* 67(1985):112–19.

Panzar, John C., and Robert D. Willig. "On the Comparative Statics of a Competitive Industry with Inframarginal Firms." *Amer. Econ. Rev.* 68(1978):474–78.

Rucker, Randal R., and Walter N. Thurman. "The Economic Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program." *J. Law and Econ.* 33(1990):483–515.

Schmalensee, R. "Another Look at Social Valuation of Input Price Changes." *Amer. Econ. Rev.* 66(1976):239–43.

——. "Consumer's Surplus and Producer's Goods." *Amer. Econ. Rev.* 61(1971):682–87.

Smith, V. Kerry. "Welfare Effects, Omitted Variables, and the Extent-of-the-Market." North Carolina State University, 1991.

Thurman, Walter N. "On the Welfare Significance and Nonsignificance of General Equilibrium Demand and Supply Curves." N. Carolina State University, 1991.

Thurman, Walter N., and James E. Easley, Jr. "Valuing Changes in Commercial Fishery Harvests: A General Equilibrium Derived Demand Analysis." *J. Environ. Econ. and Manage.*, in press.

Wisecarver, Daniel. "The Social Cost of Input-Market Distortions." *Amer. Econ. Rev.* 64(1974):359–71.

Wohlgenant, Michael K. "Flexible Consumer Demand Functions and Linear Estimation: Comment." *Amer. J. Agr. Econ.* 67(1985):141–42.

Applied General Equilibrium Welfare Analysis: Discussion

Darrell L. Hueth and Richard E. Just

We commend the organizers of this session and agree that general equilibrium (GE) welfare analysis is a topic of increasing interest. Recent research has indeed raised increasing concern about policy recommendations based on the piecemeal approach (see, for example, Lopez and Panagaria).

Because we received Thurman's paper some time ago, the usual opportunity simply to espouse our own views on the topic is not open. Nevertheless, we want to start by emphasizing that the Kaldor/Hicks compensation criterion is the foundation of applied welfare economics and that this principle is intimately related to willingness-to-pay welfare measures such as compensating variation. There is still a tendency in the profession, as reflected in some parts of Thurman's paper, to presume that the ultimate objective is measurement of consumers and producers surplus. Because Marshall was ambiguous about these terms, it is not surprising that treatments based directly on Marshallian concepts are less than clear.

The Kaldor/Hicks compensation criterion defines as a potential Pareto improvement any case where the excess of the maximum amount gainers are willing to pay exceeds the minimum amount that the losers are willing to accept to build a project or to change a policy. No judgment is made regarding whether or not compensation should be paid. It is simply a potential compensation criterion. However, sufficient income must exist in the economy to pay compensation if the decision is made to do so, a point to which we will return later. As long as economic agents have well-defined property rights to the initial situation, the appropriate measure for both the gainers and the losers is the compensating measure associated with the change. These points are made because parts of the Thurman paper suggest that the appropriate measures of welfare for both the consumer and producer are consumers and producers surplus, respectively. In fact, the triangle-like Marshallian areas behind supply and demand have welfare significance only as they approximate true willingness-to-pay measures (Hicksian surplus for the consumer and quasi-rents for the producer). The conditions under which various measures coincide are well understood and presented in detail in Just, Hueth, and Schmitz (JHS).

Failure to keep in mind that these are not identical concepts can lead to misinterpretation of the welfare significance of changes in producer and consumer surplus areas, particularly in a GE setting. For example, in equation (2) of Thurman, the first term on the right-hand side is interpreted as the change in consumer surplus, but no interpretation of the welfare meaning of this change is provided. The final term of this expression is shown correctly to measure the sum of changes in producer surplus for all input suppliers of the industry of focus. In the following equation, however, this term is converted to changes in profits or quasi-rents for these producers. In a GE context, the change in producer surplus is equal to the change in quasi-rents only when either the input suppliers are initial resource holders, and then only if the supplies are compensated, or where input suppliers purchase their inputs under conditions of perfectly elastic supply (Just and Hueth).

Although Thurman emphasizes the possiblities for conducting welfare analysis for consumer and producer groups in a single market, he does not recognize the possibilities for doing distributional analysis in the same market. As shown by JHS (pp. 188–92) the market for x_1 in figure 3 can be used to separate the welfare impacts on the producers of commodity Q from the impacts on consumers of Q and input suppliers as long as x_1 is a necessary input. That is, the difference in areas behind the ordinary demand curves passing through the two points on the GE demand curve at w_1^0 and w_1^1 can be used to estimate the welfare impact on the producers of Q. Then, using the GE demand curve, which

Darrell L. Hueth and Richard E. Just are a professor and chairman, and a professor, respectively, Department of Agricultural and Resource Economics, University of Maryland.

reflects economy-wide welfare, the impacts on consumers and producers in related markets can be obtained by subtraction.

Consider, next, Thurman's third section, in which he attempts to break some new ground in GE welfare analysis. Thurman correctly points out that the GE welfare measures suggested by JHS and others are compensated welfare measures. That is, the GE demand and supply curves are compensated supply and demand curves, and the welfare impact of introducing a distortion in one market is calculated by comparing the initial equilibrium situation with the subsequent compensated equilibrium position. The willingness to pay of individuals is calculated as though they can anticipate accompanying compensated equilibrium adjustments. Not extracting compensation will result in different equilibrium prices and quantities, and measuring willingness to pay associated with these "facts-consistent" prices and quantities has some appeal because compensation is seldom if ever paid.

The problem that arises with the noncompensated equilibrium approach, however, was discovered by Boadway. Boadway showed that, in comparing two noncompensated equilibrium situations, equilibrium could not be maintained if, in fact, compensation was paid. To illustrate how this problem can arise in the context of the Thurman paper, suppose in his facts-consistent case with an increase in the price of good 1 from P_1^0 to P_1^1 that compensating variation is calculated based on the ordinary equilibrium in market 2. That is, assume that the consumer is not compensated in market 1 as the price is increased. The welfare gain to the producer of good 2, assuming perfectly elastic input supply, is calculated as the area to the left of the supply curve between the prices P_2^0 and $\bar{P}_2$ in figure 5. If now, however, a decision is made to enforce compensation as the price of good 1 is increased, the price of good 2 would rise to P_2^1. Producers would gain more than they had expected. The welfare gain is more than the facts-consistent calculation suggests.

Suppose alternatively that the price in market 1 is initially P_1^1, income is Y^0 and the price is reduced to P_1^0. Producers in market 2 would expect price to fall to P_2^0 if compensation is not extracted from consumers in market 1. If, however, compensation is extracted from consumers in market 1, the price in market 2 declines to a price below P_2^0 as consumer income is reduced to $Y^2 < Y^0$ (assuming good 2 is a normal good). Obviously, producers in market 2 are not as well off as the facts-consistent calculations suggest they could be. Thus, the compensating variation suggested by comparison of the two ordinary equilibria is, in fact, unattainable. That is, $\Delta CS^* < \Delta\bar{W}$. This is a market version of the "Boadway Paradox" presented by Boadway in a simple general equilibrium economy.

Mishan was the first to attempt to resolve the Boadway Paradox, but his solution led to a further bothersome conclusion. The final resolution of the Boadway paradox is contained in JHS (pp. 464–69). Their resolution shows that this paradox will not arise as long as calculations are made along compensated (behavior-consistent) demand/supply curves. Calculations based on noncompensated equilibrium supply and demand curves only approximate attainable welfare effects. The CGE example presented by Thurman suggests that, for many cases, this approximation will be good.

Nevertheless, Thurman's example is instructive in pointing out that the popular CGE methodology produces a facts-consistent measure of welfare change rather than a behavior-consistent measure. The behavior-consistent measure is correct in the sense that it is attainable, while the facts-consistent CGE calculation is only an approximation. This result presents a dilemma for practitioners. The partial relationships that form the elements of a CGE model are more accessible from the standpoint of traditional econometric practice. By comparison, the direct measurement of equilibrium supplies and demands for GE welfare analysis is complicated by distortions in related markets and multiple sources of feedback. Accounting for distortions in related markets is dependent on the nature of the distortions. For example, the specific treatments required for price supports, quotas, and taxes are quite different. (On this point Harberger was somewhat ambiguous. See JHS, pp. 457–62, for additional discussion.) Multiple sources of feedback also present problems for econometric specification (JHS, pp. 207–13, 462–64). Finally, the ability of econometric practice to distinguish partial and general supplies and demands empirically is limited (JHS, pp. 200–211). The difficulty here is that as econometric practice attempts to account for general equilibrium adjustments, the number of conditioning variables tends to become unmanageably large. Identification, particularly of more flexible functional forms, becomes difficult. The premium on intuition and practical understanding that can be imposed in estimation increases. However, intuition tends to be developed through the system of partial elements that make up a

CGE model. Thus, practical econometric considerations will tend to push GE welfare analysis into a CGE mode where the Thurman assessment of consistency of facts-consistent and behavior-consistent measurements will be useful in determining the quality of approximation to true welfare measurement.

References

Boadway, R. W. "The Welfare Foundations of Cost-Benefit Analysis." *Econ. J.* 84(1974):926–39.

Harberger, A. C. "Three Basic Postulates of Applied Welfare Economics: An Interpretive Essay." *J. Econ. Lit.* 9(1971):785–97.

Just, R. E., and D. L. Hueth. "Multimarket Welfare Measurement." *Amer. Econ. Rev.* 69(1979):947–54.

Just, R. E., D. L. Hueth, and A. Schmitz. *Applied Welfare Economics and Public Policy*. Englewood Cliffs NJ: Prentice-Hall, 1982.

Lopez, R., and A. Panagariya. "On the Theory of Piecemeal Tariff Reform: The Case of Pure Imported Intermediate Inputs." *Amer. Econ. Rev.*, in press.

Mishan, E. J. "The Use of Compensating and Equivalent Variation in Cost-Benefit Analysis." *Economica* 43(1976):185–97.

Exact Welfare Measures of the Price Effects of the U.S. Dairy Program: Discussion

Wen S. Chern

I am delighted to have this opportunity to review LaFrance's article and to gain additional insights on the recent literature in applied welfare economics. During the last two decades, among the most cited articles are the papers by Willig and Hausman. They and other economists have worked on methods to compute correctly the consumer surplus (CS), the compensating variation (CV), and equivalent variation (EV). Precisely, these investigations focused on how to use the observed Marshallian demand function for computing the theoretically correct Hicksian measures of CV and EV.

LaFrance's paper represents the state of the art in the development of empirical estimates of Hausman's exact consumer's surplus and deadweight loss (welfare triangle). This and other recent developments represent one of the most important uses of the duality theory. The basic idea is very simple. With an observed Marshallian demand function, we can apply the duality theory (particularly Roy's identity) to recover the indirect utility function and thus the expenditure function. These functions can then be used to compute the exact measures of CV and EV. Unfortunately, to derive the expenditure function from the Marshallian demand is not a simple matter. If often involves quite a bit of calculus in solving a set of differential equations. Even a simple linear or log-log demand equation results in a highly nonlinear indirect utility function and expenditure function. The theoretical works by Hausman, LaFrance, and others provide explicit derivations of these relationships and demonstrate approaches for carrying out the complex econometric estimation.

Wen S. Chern is a professor, Department of Agricultural Economics and Rural Sociology, Ohio State University.

Contributions

LaFrance's paper represents an extension of Hausman's work in that he develops similar comparisons of welfare measures employing a set of demand functions for multiple price changes. Hausman's paper covered the cases of n commodities but did not consider either a demand system or multiple price changes. Therefore, LaFrance's paper addresses a much more complex problem than any previously addressed in the literature. I am sure the paper will generate a lot of interest in further applications and, hopefully, continued refinements.

Second, the paper demonstrates that the imposition of complex integrability restrictions in a complete demand system is doable. These restrictions involve the Slutsky matrix and are highly nonlinear. The econometric task is not trivial. The experience he went through would be very useful for future practitioners. The convergency problem is often encountered in estimating a nonlinear system with iterative three-stage least squares. The solutions to these econometric problems would be valuable and perhaps need to be more completely documented and be made available to interested readers. This econometric complexity also points out the need to search for a better functional form in future research.

Third, the empirical application to the evaluation of the federal dairy program is both important and controversial. The paper will undoubtedly generate further debate and discussion. Despite several caveats I will mention later, the calculated welfare measures and comparative results appear plausible. However, I must caution the reader that, despite the improved methodology, the computations are highly conditional upon whether or not the federal dairy program would result in higher or lower retail prices of dairy products. This is by no means a

well-settled issue. I will provide further discussion of this later.

Comments

My comments are focused on several methodological issues and policy simulation. My first comment pertains to functional form. I agree with LaFrance that we are often interested in a subset of commodities, and data limitations often prevent us from modeling a truly complete demand system. Therefore, LaFrance, in his earlier work, developed and advocated what he called "incomplete demand systems" using linear or logarithmic forms. He and his colleagues demonstrated that some of these incomplete demand systems are indeed quite flexible and lend themselves to the derivation and imposition of some important properties such as symmetry conditions.

Perhaps, not surprisingly, he continued to advocate his incomplete demand systems in this paper. As we have often seen, the computations of consumer surplus and other welfare measures are typically based on a single-equation model of linear or log form. Therefore, the use of an incomplete demand system is certainly an improvement over single-equation approaches. However, there are three shortcomings in the methodology employed in this study.

(*a*) The inclusion of other foods remains incomplete, and the categories are chosen somewhat arbitrarily. One is not sure whether there are really gains in including more than one subgroup of the other foods. If all other foods and other goods are aggregated into a composite good, then one can use a complete rather than incomplete demand system.

(*b*) The linear CS, concave CS, and linear CV are based on a linear demand model, while the weakly integrable model is based on a nonlinear demand system. Therefore, the differences in various welfare measures may result from the differences in functional form rather than from the imposition of the integrability restrictions. When Hausman conducted his comparison, he used just one functional form.

(*c*) The use of a linear demand system makes it easier to compute consumer surplus. However, the corresponding expenditure function is complex and highly nonlinear. Consequently, the computation of the exact CV is also complex. On the other hand, many commonly used complete demand systems, such as the almost ideal demand system (AIDS) and translog, have their expenditure function and indirect utility function well defined in the literature. Therefore, if we believe in the exact CV measure and would use the indirect utility function or the expenditure function, then perhaps these well-tested functional forms are better alternatives than the linear or semilog incomplete demand systems.

My next comment is on empirical application. In the paper, LaFrance also estimated regression models for predicting the retail prices of dairy products as functions of government price support programs. These are ad hoc reduced-form equations. The choice of explanatory variables appears to be reasonable as it includes both demand and supply shifters. However, one may be curious about why the nominal rate of return on AAA corporate bonds is selected. His predicted results indicate that federal dairy programs have increased the retail prices of all dairy products. These impacts may be very plausible in the short run. However, in the long run, the relationship is not so clearcut. Gardner (pp. 290–300) recently developed some interesting theoretical results. He argued that the price support program may be viewed as a risk-reducing policy which may cause a shift in supply curve. He showed that the effects of a risk-reducing policy on product price would be a function of the risk premium if farmers are risk averse. As an example, Thraen and Hammond estimated a milk production model incorporating price risk. They estimated that without the dairy price support, the price of manufacturing milk would be 23% to 36% higher. Consumers gained roughly $3.00 per hundredweight. For 1.2 billion hundredweight, the total gain would be $3 billion to $4 billion per year. Gardner indicated that the estimate seemed high but did not dispute the direction of the impact. I am not suggesting whether LaFrance's estimate of a price increase is more or less credible than other estimates of a price decrease. However, it is important to remind researchers and policy makers to be cautious in using these empirical results. In any case, whether or not the dairy program would result in higher or lower prices would not affect the basic methodology developed in this paper.

Conclusions

LaFrance's paper represents an important extension of Hausman's work, attempting to measure welfare changes for the case of multiple products and multiple price changes. He provides some new insights on those methods. Nevertheless, I believe the methods employed in this paper leave room for additional exploration in se-

lecting alternative functional forms which may accommodate easier estimation of demand parameters, indirect utility function, and expenditure functions.

References

Gardner, B. L. *The Economics of Agricultural Policies*. New York: Macmillan Co., 1987.

Hausman, J. "Exact Consumer's Surplus and Deadweight Loss." *Amer. Econ. Rev.* 71(1981):662–76.

Thraen, C., and J. W. Hammond. "Price Supports, Risk Aversion, and U.S. Dairy Policy." *Econ. Rep.* 83-9, Dep. Agr. and Appl. Econ., University of Minnesota, 1983.

Willig, R. "Consumer's Surplus Without Apology." *Amer. Econ. Rev.* 66(1976):589–97.

Abstracts

Symposia

Toward Increased AAEA Involvement in Economic Education. Michael E. Wilson, presiding (Lee Wilson & Company), Kimberly Reda-Wilson (Economic Education Consultant, Reda Enterprises), Donald O. Fell (Florida Council on Economic Education), Jeanette Bennett (Parkin Elementary School, Arkansas), and Marilyn Hollis (Parson Hills Elementary School)
The ability to apply economic reasoning does not happen incidentally but requires early systematic instruction in basic economic concepts applied to past and contemporary issues. The Joint Council on Economic Education (JCEE) has served to legitimize economic education as a subfield within economics and is a recognized leader in developing and implementing a comprehensive economic education program in grades K-12. The land grant system has not fully tapped into the JCEE mission and vice versa. Recognizing and working with each other would serve the dual purpose of revitalizing the land grant mission *vis-à-vis* a current social problem and of expanding the JCEE delivery system. Reda-Wilson proposed that the AAEA profession accept responsibility and exhibit professional concern for economic education at the pre-college level. Hollis testified that her first grade students were able to comprehend basic economic concepts. Bennett discussed how agriculture is an inspiring medium with which to teach economics and how students' basic test scores increased in her school after the introduction of economics. Fell depicted successful strategies in obtaining financial corporate support for economic education in Florida. Wilson welcomed AAEA involvement in economics if it, indeed, is on AAEA's agenda.

Preservation and Restoration of Wetlands: The Challenge of Economic-Ecological Input/Output Modeling. Steven E. Kraft, organizer and moderator (Southern Illinois University), Paul Dye (The Nature Conservancy), Andrew French (U.S. Fish and Wildlife Service), Richard Johnson (National Ecology Research Center), Roger Beck (Southern Illinois University), and Dennis Robinson (Institute for Water Resources, Army Corps of Engineers)
Presenters and the audience discussed the problems associated with conducting economic impact analyses for wetland areas located in sparse economic regions. Problems addressed covered the meshing of ecological and economic concerns within the framework of traditional input-output analysis, problems with existing data bases and their frequently incompatible scales of reference, use of the biosphere reserve model for combining economic and ecological data to enhance ecological diversity while maintaining the greatest number of options for using the buffer areas, evaluation of ecological functions, and the use of hybred input-output models.

Can Agricultural Economics Contribute to the Profession of Agribusiness? Michael Cook (University of Missouri), R. James Hildreth (Farm Foundation), William D. Gorman (New Mexico State University), and Joseph Havlicek (Ohio State University)
The objective of this symposium was to increase the understanding of the current and potential contributions of the applied field of agricultural economics to the profession of agribusiness management. Cook provided an overview of the inherent characteristics of the agricultural sector that necessitate unique risk management and intervention risk attention from a multitude of disciplines if the attributes of our output are to fulfill the needs of the end users. Hildreth stressed the importance of understanding agribusiness demand for the outputs of agricultural economists. Receiving particular attention were the concepts of market equilibrium, relative expected costs, reduction of logical positivism, and relevance of public choice literature. Gorman reviewed the origins of the recently founded International Agribusiness Management Association and its objectives of coordinated research, strengthened degree programs, dissemination of information, and development of networks. By use of a Venn diagram, Havlicek elaborated on the degrees of homogeneity and heterogeneity of interests in the agricultural economics/agribusiness management fields. His challenge to the profession was to know more about the intersection of the two than we do presently.

The Effect of Grain Quality on U.S. Competitiveness in the World Market. William Lin, presiding (ERS USDA), Lowell D. Hill (University of Illinois), Brian Adam and Kim Anderson (Oklahoma State University), and William W. Wilson (North Dakota State University); discussants: Harvey Kiser (Kansas State University), Winston Wilson (U.S. Wheat Associates), Bengt Hyberg, and Mack Leath (ERS USDA)
In recent years there have been increasing concerns over the quality of grains exported from the United States versus the quality of competitors' grain. This symposium examined some issues related to the effect of selling cleaner grain on U.S. competitiveness in the world market. Lin compared quality of grains exported from the United States versus the quality of competitors' grain. He noted that grains exported from the United States to Japan and Taiwan tended to contain higher dockage for wheat, high broken kernel and foreign material for corn, and higher foreign material for soybeans. Hill contended that tightening grain

grades and standards to bring about cleaner U.S. exported grains would have little effect on regaining lost U.S. market share. Adam and Anderson reported preliminary estimates of costs and benefits of cleaning winter wheat. Wilson reported preliminary results of measuring import demand for cleaner grain by using the input characteristics model.

The AAEA, Academia, and Agricultural Economists: An "Outsiders" Perspective. Paul Wilson, presiding (University of Arizona), Marvin Duncan (North Dakota State University), Marcia Glenn (Kraft General Foods), Susan Offutt (Office of Management and Budget), Karl Skold (Quaker Oats), and Neil Conklin (Arizona State University)

This symposium explored concerns that the AAEA has become or is becoming an academic association rather than a professional association which celebrates its diversity. Duncan called for more policy-oriented research and a broader focus for the profession (e.g., less relative emphasis on farm management). Glenn emphasized the importance of outstanding quantitative, communication, and problem-solving skills for our students interested in entering industry. Offutt suggested that more debates and discussions at annual meetings would better serve a diverse profession. Skold lamented the fact that industry economists have serious constraints on their time and challenged the profession to repackage and/or market the annual meetings in a more timely and effective manner. Conklin expressed concern about growing undercurrents of professional disrespect between economists with academic, industry, and government appointments within the association.

Constitutional Economics and Policy Reform in Development. John McMillan, organizer (Institute for Policy Reform), Stan Johnson, moderator (Iowa State University), Gordon Rausser (University of California, Berkeley), Norm Nicholson (USAID), Dan Sumner (North Carolina State University and USDA), John McMillan (Institute for Policy Reform), and David Bullock (University of Illinois)

Economists are increasingly examining the way in which economic policies are made in order to understand seemingly bad policies. This symposium defined topics and discussed extensions of this new research agenda. Rausser reviewed the "toolbox" of this research branch, ideas such as credibility of reforms, cooperative and noncooperative game theory, bargaining power and access to the decision-making process. Nicholson argued that while researchers are familiar with innovations induced in institutions by changing factor prices and transaction costs, innovations which feed in the reverse direction are also possible. Indian agricultural policy and Indian federal structure in the green revolution period was used to illustrate institutional changes which induced changes in economic variables. Sumner discussed the applicability of institutional models, with illustrations from U.S. policy, arguing that the form of agricultural legislation is influenced by the committee structure of the U.S. Congress. McMillan sketched a three-sector model in which institutional change could be measured, and in which a fraction of economic growth could be attributed to changes in institutions. Bullock emphasized that most institutions have economic causes, and that the root cause of government policy change looks underneath existing institutions to find ultimate economic causes.

The Relationship between International Trade Development Centers (ITDCs) and the Private Sector. Mary A. Marchant, organizer and moderator (University of Kentucky), Clarke R. Burbee (CSRS USDA), Michael R. Reed (University of Kentucky), Dan L. Gunter (Florida Department of Citrus), James E. Ross (FAS USDA)

This symposium (*a*) provided the audience with a better understanding of the congressionally created ITCDs, (*b*) discussd how ITDCs enhance international agricultural trade by working with the private sector and government agencies, and (*c*) addressed questions that arise as a result of the unique structure of ITDCs, where most are housed in universities yet work actively with the private sector to enhance agricultural exports. Information provided by Burbee decribed how ITDCs were created, their current status, and prospects for new ITDCs. Reed discussed the functions of the Center for Agricultural Export Development (CAED), as an example of an operating ITDC, focusing on the relationship between the CAED and the private sector. Gunter discussed how ITDCs can meet the needs of the private sector. Ross discussed the relationship between ITDCs and other trade organizations.

Cooperation of Land Grant Universities with the Soviet Union and East European Counterparts in Teaching, Service, and Research in the Areas of Agricultural Economics. David L. Chicoine, presiding (University of Illinois), Lowell D. Hill (University of Illinois), Joseph Havlicek, Jr. (Ohio State University), Stanley R. Johnson (Iowa State University), and Wojciech J. Florkowski (University of Georgia)

Recent changes in the Soviet Union and East European countries has resulted in the transition from central planning to a market-oriented economy. The transition requires restructuring of agricultural economics teaching, research, and extension. This symposium examined opportunities and challenges offered by the formerly centrally planned economies to U.S. land grant universities. Hill focused on the needs of providing timely and accurate market information for decision making on private farms in Poland. He illustrated the impacts of farmers lacking readily available information, which can result in the mis-

allocation of resources. Havlicek summarized his experience teaching basic agricultural economics courses in Czechoslovakia stressing similarities in teaching needs across the region. Johnson spoke of negotiating cooperative agreements with agricultural and economics institutes in the Soviet Union at the central and republic level. He offered a list of institutes interested in such a cooperation. Florkowski spoke of the consequences of neglecting the development of agricultural economics as an independent discipline.

The Food, Agriculture, Conservation, and Trade Act of 1990—Implications. Freddie White, presiding (University of Georgia), Daryll Ray (Oklahoma State University), Carol Kramer (Resources for the Future), Maury Bredahl (University of Missouri), and Bob Spitze (University of Illinois)
While the 1990 act does not represent a dramatic departure from recent legislation, it places more emphasis on environmental protection and increased flexibility for farmers. Ray contended that expected net farm income will do well to hold 1990 levels and could decline by 25% over the life of the act. Price and income instability is apt to increase. Kramer said that in spite of federal budget cuts in many areas, food assistance programs will receive at least level funding. Standards for organic foods and required pesticide record keeping by farmers are aimed at addressing consumers' concerns over food quality. With respect to agribusiness, Keith mentioned that the crop acreage remaining idle under the new act means less sales for farm input suppliers, less revenue from handling grains and oilseeds, and, with the apparent dismantling of the farmer-owned reserve, less storage revenue. In the international trade arena, Bredahl contended that many of the impacts on U.S. grains and oilseeds under current GATT proposals are already incorporated into the 1990 act. Spitze discussed the implications of the 1990 act for further policy research in the areas of policy-making process, new and changing institutions, and emerging problems relating to instability, the environment, and food quality.

Sustainable Agriculture: A New Mandate for the Agricultural Economics Profession. Patrick Madden, presiding (University of California), Patricia Norris (Oklahoma State University), Fred Hitzhusen (Ohio State University), Kenneth Baum (Office of Agriculture, US-AID), and John Ikerd (University of Missouri)
The 1990 farm bill includes a clear mandate for public research and education to address the issue of sustainable agriculture. This symposium addressed the opportunities and responsibilities of agricultural economists to respond to this mandate. Madden called upon agricultural economists to work within interdisciplinary teams to develop a more holistic, systems approach to farm resource management. Norris discussed five different microeconomic concepts, pointing out where traditional analytical approaches could be applied and where new or revised analytical approaches are needed to address the sustainability issue. Hitzhusen demonstrated applications of macroeconomic analysis to questions of agriculture and the environment, with emphasis on off-site impacts. Baum pointed out opportunities and needs for agricultural economists to participate in a growing number of well-funded international programs oriented toward sustainable development. Ikerd concluded that economic and environmental forces are shaping a postindustrial resource development paradigm which relies more on human factors and thus makes agriculture more supportive of rural communities.

Establishing and Maintaining a Teaching Network: The Example of a Futures and Options Course. Steve Turner, organizer and moderator (University of Georgia), Joe Davis (University of Kentucky), Donald McDowell (North Carolina A&T), Foy Mills (Abilene Christian University), Richard Jelinek (Chicago Board of Trade)
One of the major professional costs of teaching is developing, organizing, and maintaining materials for courses taught. This symposium demonstrated the procedure, product, and benefits of implementing a network approach to teaching a futures and options course. A book is available (from Turner) that contains course outlines, problem sets, and exams from 49, 23, and 28 teachers, respectively. Davis discussed the benefits (new ideas, etc.) of a teaching network from the 1862 land grant and AAEA perspective. McDowell assessed the need for a futures and options course in the 1890 land grant university curriculum. Mills addressed some of the unique problems and needs of faculty at non-land grant institutions and the opportunities for addressing these through utilizing teaching networks. Jelinek presented an overview of the CBOT's educational programs and opportunities.

Toward Improving the Microlevel Economic Evaluation of Technology Adoption and New Production Systems. William Crosswhite and Richard Magleby, organizers (ERS USDA), Amy Purvis and William Boggess (University of Florida), John Ikerd (University of Missouri), Andrew Manale (EPA), and Susan Offutt (OMB)
Farmers, researchers, and policy makers are urged to think uniquely about water-quality-oriented technological innovations, adoption, and evaluation. Grappling with water quality problems means recognizing a new constraint rather than considering an opportunity to improve efficiency or productivity. Farm-level economic effects of changing farm practices and production systems should be measured in terms of (*a*) sustainability involving operator goals, values, technology, individual knowledge and resources, and opportunities; (*b*) short-run viability (competitiveness and profitability); and (*c*) long-run survival (envi-

ronmental protection and resource conservation). Numerous difficulties are associated with linking process and farm decision models including multidisciplinary research problems, aggregation difficulties, and conceptual differences in the structure of physical and behavioral models. A blending of the voluntary approach and limited regulation may be needed to establish equitable game rules that define acceptable economic activity for the numerous resource and environmental conditions. The challenge is to improve evaluation of both technical solutions and progress in pollution abatement in agriculture.

Can We Be Analytical About the Political Economy of Policy? Milt Halberg (Pennsylvania State University), Jim Hildreth (Farm Foundation), and Bob Spitze (University of Illinois) organizers; Jim Hildreth, moderator; Larry Martin (University of Guelph), Kristen Allen (consultant), Allan Schmid (Michigan State University), Gordon Rausser (University of California, Berkeley), Barry Flinchbaugh (Kansas State University), and Bob Spitze (University of Illinois)
Political economy has increasingly reentered the literature and discussions of public agricultural and food policy. This symposium shared conceptual framework for the roles of political economy in policy research, education, and policy making. Martin stressed the decision processes and role of multinational businesses in national policy. Allen reported from a survey that members of Congress use very diverse information, particularly related to their constituency, and containing little economic analysis. Schmid expressed concerns about the search for a single principle of political economy and about emphases on dichotomies, as free market versus intervention. Rausser agreed literature had not recognized the underlying relationships between constitutional law and preference weights in policy analysis. Flinchbaugh believed political economy could be analytical, with more economics in politics, not the opposite. Spitze sketched a participatory public policy process conceptual framework, which expresses political economy as more than economics.

Teaching and Research Demands on Extension Economists. Gary Fairchild (University of Florida), Karen Klonsky (University of California, Davis) and George Patrick (Purdue University) organizers; Gary Fairchild, moderator; David Kenyon (Virginia Tech), Gary Fairchild and David Chicoine (University of Illinois), Ernest Davis (Texas A&M University), and Marc Johnson (Kansas State University)
As extension economists become more involved in teaching and research activities, implications for educational programs emerge. Demands of class schedules and preparation, involvement in grants, issues centers, and basic research projects have a variety of implications for extension economists. The paradigmatic extension economist of the 1990s faces choice spectrums which require the attention of both the individual and the profession. Kenyon discussed conflicts and compatibility between teaching and extension, noting the importance of a well-defined, focused educational extension program, a carefully designed delivery system, and the difference between programs based on education versus service. Fairchild and Chicoine discussed trade-offs between disciplinary research and program delivery, noting that basic research can be complementary to an extension program and help maintain an analytical presence as well as professional flexibility and mobility. Value to a department includes improved quality of research and reputation. Davis provided a view from a traditional extension specialist, noting the importance of interpreting research results and developing decision aids for commodity groups, politicians, and university administration. Survival depends on support, credibility, objectivity, and effectiveness. Johnson shared a view from a department chair, noting the competitiveness among functions and the value of involvement of extension economists in related teaching and research activities.

Beyond Beef: Added Dimensions of Pacific Rim Livestock Trade. Alan J. Webb, presiding (ERS USDA), Dermot Hayes (Iowa State University), Laurian Unnevehr (University of Illinois), John Dyck (ERS USDA), and Keiji Ohga (Ministry of Agriculture, Forestry and Fisheries, Japan)
Pacific Rim beef trade has received most of the attention of agricultural trade economists in the past decade despite the remarkable growth in trade of pork, poultry, dairy, and egg products. This has occurred over a period in which the growth of U.S. exports of feed grains and oilseeds to the Pacific region has been flat. The symposium emphasized the effects of changes in policies, technologies, and economic factors on the location of pork and poultry production in the Pacific Basin. Unnevehr argued that understanding lags or barriers to successful production technology transfer was the key to understanding the future of these markets. Hayes observed that reduced costs associated with processing and shipping technology would improve prospects for U.S. meat exports. Dyck compared feed efficiency rates and costs for East Asian countries and argued that improvements in efficiency will reduce feed trade. Ohga cautioned against underestimating the competitiveness of the Japanese livestock industry. Audience participation focused on the overall implications of the changes in technology and trade barriers for U.S. exports and the role China might play in Pacific meat and feed grain trade in the next decade.

Information and Data Dissemination on Compact Discs: New Technology for Research. James

Horsfield, organizer (ERS USDA), Edward Reinsel, presiding (ERS USDA), Gary McCone (National Agricultural Library, USDA), Douglas Miller (Bureau of the Census), Louise Letnes (University of Minnesota)
CD-ROM technology has the potential to revolutionize information and data dissemination by sharply reducing both the direct and indirect costs of using large databases. Compact discs hold up to 650 million bytes of digital information on the small discs used for recorded music. County data from the 1987 Census of Agriculture, for example, is now disseminated on one CD-ROM, which also contains similar data for the 1978 and 1982 censuses. Also, scholarly journals are increasingly available on CD-ROM. McCone reported on National Agricultural Library experience with CD-ROM, including the dissemination of photography and digital audio material on discs in addition to conventional text and graphics. Miller discussed Census of Agriculture development of CD-ROMs for data dissemination and the rapid adoption of the technology by analysts using personal computers. Letnes presented the results of an AAEA survey of CD-ROM use in departmental libraries and discussed the types of information and data most needed by researchers. Participants gained an appreciation for the costs and benefits of using CD-ROMs and for the need for improved dialogue between CD-ROM publishers and users in order to develop useful products for research.

Targeting Educational Programs to Women in Agriculture. Damona G. Doye, presiding (Oklahoma State University), Charles Griffin (Kansas Farmers Assistance Counseling and Training Service), Deb Rood (University of Nebraska), Richard Jelinek (Chicago Board of Trade), Bill Tierney for Marvin Fausett (Kansas State University), Wayne Hayenga (Texas A&M University)
Women play many important roles in production agriculture, including farm operator and manager, partner in farm and family decision making and landowner. Changes in women's role and the need for higher levels of management on farm provide opportunities for targeted educational programs. This symposium offered insights and lessons learned from organizers and presenters of programs targeted to women. Griffin discussed differences in decision making, sources of stress, and role reclarification by gender. Rood cited evidence of women's role as information gatherers, using management conferences for women in agriculture as an example. Jelinek discussed experiences in providing marketing workshops at three levels of difficulty for women in twenty-two states. Tierney related differences observed in marketing clubs in which women participated. Hayenga focused on the educational needs of women as landowners. Presenters noted that women are, in general, enthusiastic students and appreciate the opportunity to ask questions in a nonthreatening environment.

The Economic and Policy Implications of Animal Welfare and Animal Rights Movements for U.S. Agriculture. Harold D. Guither (University of Illinois), organizer and moderator; Charles Lambert (National Cattlemen's Association), John Dietrich (American Veal Association), Wes Jamison (Oregon State University), Marty Vanier DVM (Kansas State University) and Bradley Miller (Humane Farming Association)
Animal welfare was defined as concerns for the humane treatment of all animals without concern for their ultimate use; animal rights deals with the philosophy that human and nonhuman animals have equal rights and nonhuman animals have the right not to be used for any purpose by humans. Charles Lambert emphasized that animal welfare and animal rights movements are continually soliciting money to maintain their programs and gain public support. John Dietrich reported the rising costs of veal calves as a result of government dairy buyout programs and declining dairy cow members. He emphasized that veal production is enhanced by two surplus products, dairy bull calves and surplus dried milk. He did not feel that veal calves were mistreated. Marty Vanier pointed out that the animal welfare and animal rights movements have influenced the veterinarian's teaching, surgery techniques, research methods, and recommended health care guidelines. Wes Jamison described the typical animal rights activist as caucasian, female, 30-years old, $33,000 annual household income, highly educated, well informed, urban, professional, and holding membership in environmental organizations. He also cited evidence of wide variations in the degree of activism among members of animal rights organizations. Miller emphasized the potential impact that treatment of animals can have on consumers, and the environmental image of agriculture. Certainly, a wide difference of philosophical values and economic perspectives for the treatment of animals in our society. Symposium participants became aware of these differences and the implications for their future teaching, research, and extension programs.

Regional Research: Lessons for a Global Research Agenda. Robert L. Beck, moderator (University of Kentucky), Glynn McBride (Michigan State University), Truman Graf (University of Wisconsin), Charles E. French (Charles E. French and Associates), Elmer Baumer (Ohio State University), Paul L. Farris (Purdue University), Roland R. Robinson (CSRS USDA), Don Anderson (North Dakota State University) and Thomas Klindt (University of Tennessee)
The symposium focused on three aspects of regional research: (*a*) public impacts of regional research using dairy market regional research as a specific example, (*b*) professional impacts, and (*c*) adaptation of the regional approach to international cooperative research. Examples of results from five decades of regional dairy-marketing research stand as evidence

that regional research can be timely and relevant. Professional impacts, although somewhat more difficult to quantify, are important. Perhaps the most important contribution of regional research has been to provide a forum leading to cooperative professional dialogue, planning, and much of the coalescing of research professionalism during the past few decades. The agricultural economics profession has benefited immeasurably from this aspect of regional research. Because U.S. agriculture now operates in a global environment, there is need to shift, or expand, the focus of marketing research to include global problems. In incorporating the global dimension into our research agenda, there is much that can be learned from the regional approach.

Sustainable Agriculture Under the 1990 Farm Bill. Emily A. McClain, Harold M. Harris, and Johnny W. Jordan, organizers (Clemson University); C. Parr Rosson, moderator (Texas A&M University); Chuck Hassebrook (Center for Rural Affairs), Michael D. Hammig and Johnny W. Jordan (Clemson University), John Ikerd (University of Missouri), and John Haberern (Rodale Press)
New provisions in the 1990 farm legislation created confusion about impacts on U.S. agriculture and the role of sustainable agriculture at the farm and aggregate levels. This symposium reviewed the background and issues relating to "sustainability" as implied and mandated in the farm bill. Hassebrook contrasted the flexibility of the new sustainable agriculture provision with the rigidity of the 1985 farm bill, emphasizing how these provisions allow farmers to be better stewards of the land. Hammig and Jordan used computer simulation techniques to analyze the impacts of the farm bill's integrated farm management program option (IFMPO) on a South Carolina case study farm, showing that the IFMPO improved the farm's financial position. Ikerd noted that declining incentives for specialization implies adjustment for rural communities and existing infrastructure; possible regional shifts in production away from continuous row cropping was debated. Haberern emphasized policy's role as a catalyst for sustainability, but noted that change proceeds slowly.

Value Added by Agricultural Production. James Johnson, moderator (ERS USDA), Bernard Stanton (Cornell University), Gerald Schluter and John Jinkins (ERS USDA), Greg Hanson (Penn State University)
Statistics showing how value-added creation varies among community specialities are not available, nor has the interest in agricultural value added resulted in a consensus among agricultural economists about the most appropriate way to measure value added. Bud Stanton explained value added, discussed the controversies, and proposed a useful value-added measure for agriculture. Gerald Schluter pointed out some problems in attempting to measure the value added from agriculture in isolation from other sectors of the economy. John Jinkins described results from an effort to measure agricultural value added using aggregate national data. Greg Hanson showed how the value added has been shared by the stakeholder team consisting of farmers, labor, lenders, landlords, and government. Audience participants raised concerns with the measurement of poultry and feeder cattle value added, and the critical nature of identifying individual deflators for both receipts and expenses. More comparisons with European measures of value added were suggested. Reaction was favorable for USDA publication of a value-added series for agriculture.

Law, Institutions, and International Agricultural Trade. Michael Cook, moderator (University of Missouri), William Quarles (Sunkist Growers), Robert McGeorge (University of Nebraska), Fred Boadu (Texas A&M University), and Lance Kotschwar, Doug Simon, and Wes Peterson (University of Nebraska)
Agreements on the rules to govern international agricultural trade are made operational through the establishment of legal processes. This symposium provided a legal and institutional perspective on agricultural trade based on the expertise of legal practioners and scholars. Quarles provided an overview of the legal framework for agricultural trade based on the distinction between domestic statutes that affect trade, bilateral, and regional agreements on trading rules within geographic areas and multilateral agreements aimed at setting rules for all trading nations. McGeorge suggested that extending such measures as the GATT escape clause to include food security concerns might facilitate agreement on broad multilateral rules. Boadu argued that constitutional liberties are an essential precondition for the realization of effective regional integration in the developing countries of West Africa. Finally, Kotschwar, Simon, and Peterson traced the history of attempts to regulate the use of technical standards in international trade and described the kinds of legal and institutional conflicts that have arisen over trade in livestock products.

Hedonic/Characteristic Price Analysis in Agricultural Economics: Progress, Issues, and Needs. Don Ethridge, presiding (Texas Tech University), Steve Morse (Texas Tech University), George W. Ladd (Iowa State University), Kenneth Bowman (Clemson Unversity), William W. Wilson and Demcey Johnson (North Dakota State University), David Eastwood (University of Tennessee), and David W. Price (Washington State University)
Hedonic price analysis and characteristics models are receiving increasing attention and use in studying consumer demand and commodity pricing. This symposium provided a review of past and current research, assessment of theoretical and empirical issues, and future research needs in these areas of

hedonic or characteristic prices. Morse and Ladd reviewed characteristics demand theory and empirical analysis as applied to consumer goods, with emphasis on food, and suggested areas for current and future research. Bowman and Wilson/Johnson emphasized hedonic analysis as it relates to agricultural commodities markets. They emphasized the long history of hedonic studies and the need to understand the separate supply and demand causes of characteristic prices. Eastwood and Price focused their attention on the theoretical and empirical issues, also focusing most of their attention on consumer demand issues as opposed to commodity markets. Functional form identification and nonseparability of characteristics were two of the problems identified.

Guardians of the Profession? The Review Process of Selected Agricultural Economics Journals. Dan L. McLemore, presiding (University of Tennessee), Larry W. VanTassell (University of Wyoming), Peter J. Barry (University of Illinois), John R. Brooker (University of Tennessee), Lindon J. Robison (Michigan State University), Loren Tauer (Cornell University), David W. Price (Washington State University)
The ability to work with a reviewer and editor in the review of a journal manuscript is critical in the career of most agricultural economists. This symposium examined the review process of major agricultural economics journals. VanTassell presented results from a survey of reviewers and authors concerning their perceptions of the review process of four agricultural economics journals. Topics included attitudes toward a blind review process, how the reviewer's role is viewed, perceptions of the review process, correspondence between reviewers and authors, and what reviewers are looking for in a manuscript. Barry suggested approaches for authors to use to enhance their chances for acceptance. Robison emphasized the need for journals to encourage the use of innovative approaches in research. Tauer suggested that if we concentrate on good research that is communicated well, publication will follow regardless of flaws in the review process. Tauer also called for additional mentoring of Ph.D. students in the publication process. Price explained the review philosophy and data disclosure policy of the *WJAE*. Brooker discussed how the editorial council system of the *SJAE* differed from the other journals.

Harmonization of Information Systems: A Farm Business Model Approach. Edward Reinsel, organizer (ERS USDA), Robert Jolly, presiding (Iowa State University), Stephen B. Harsh (Michigan State University), Vinus Zachariasse, (Agricultural Economics Research Institute, The Netherlands), Marvin T. Batte (Ohio State University)
There is frustration resulting from the lack of correspondence between needed data and their availability through existing systems. Farm business modeling and information system harmonization offer the potential for improved and more compatible data for a wide range of uses. Harsh explained his view of a harmonized information system, listed factors that will encourage or constrain growth in the use of information technology, identified farm-level issues, and outlined needed data and information and knowledge flows. Zachariasse reported on farm management information systems planning and development in the Netherlands where such effort have made considerable progress. Batte suggested what the potential of farm business modeling and information system planning may be in the U.S.—what kind of system is feasible and how it can be developed. Participants gained an improved understanding of harmonized farm information systems, better recognized resources demands, and assessed likely problems.

The Political Economy of Food Assistance Programs: Case Studies from the Developing World and the United States. Laurian Unnevehr, presiding (University of Illinois), Margaret Grosh (World Bank), Cathy Jabara (Cornell University), Carol Kramer (Resources for the Future), and Nicole Ballenger (USDA)
Attention has turned recently to cushioning the transitional hardships of structural adjustment and to designing social safety nets consistent with a smaller role for government. Food assistance programs have become an important focus. In particular, how can countries move from expensive general food subsidies to well-targeted schemes? At the same time, forces shaping agricultural policy reform in the United States, such as the GATT and budget pressures, suggest that commodity surpluses motivating both international and domestic food aid will be reduced. This symposium focused on political economy of food assistance programs in several case studies. Jabara analyzed the impact of the Gambia's structural adjustment program on rice prices and discussed the government's decision to avoid intervention in this staple food market. Kramer presented the challenge to the Tunisian government in moving from an expensive and distortive general food subsidy system to a scheme targeting the poor. Grosh presented the main reasons for the success of the Jamaican food stamp program, including the use of existing institutions, appropriate self-targeting, and a simple means test. Ballenger, based on interviews with emergency food distributors in the District of Columbia, asked if U.S. commodity distribution should be delinked from government-held stocks and have a long-term role as a supplement to food stamps.

U.S.-Mexico Free Trade: Identifying the Research and Extension Agenda. C. Parr Rosson, III, and Amy Angel, organizers (Texas A&M University), Stanley M. Fletcher, presiding (University of Georgia), Terry Francl and Mickey Paggi (American Farm Bureau Federation), John C. Dunmore

and Bob Robinson (ERS USDA), Eduardo Segarra (Texas Tech University), and C. Parr Rosson, III (Texas A&M University)
Trade liberalization with Mexico has major consequences for U.S. agriculture. Recent trends in agricultural trade indicate that the U.S. will experience increased demand for feed grains, cattle, and meat, while U.S. producers of labor-intensive fruits and vegetables will experience more import competition. This symposium identified key issues of concern to both the public and private sectors in an attempt to improve coordination of research and extension efforts. Francl and Paggi outlined the AFBF agenda, concluding that U.S. seasonal tariffs on fruits and vegetables, along with market orders will be concerns for Mexico, while Mexican import licenses and scientific justification of phytosanitary and sanitary measures are key concerns to U.S. producers. Dunmore and Robinson indicated that ERS research will focus on three key areas: economy-wide impacts of more open trade, aggregate commodity impacts, and regional impacts. Segarra discussed the importance of the duality of agriculture in Mexico and the need to address the complementary trade patterns affecting some sectors. Rosson indicated that extension can have a major role in educating constituents about the process of negotiations and subsequent impacts while assisting industries to adjust to both the problems and opportunities of liberalized trade.

Leadership Skills, Opportunities, and Experiences in the Agricultural Economics Profession. Sarahelen Thompson, presiding (University of Illinois), Marc Johnson (Kansas State University), Sandra Batie (Virginia Polytechnic Institute and State University), David Chicoine (University of Illinois), and Susan Offutt (Office of Management and Budget)
This symposium was part of CWAE's continuing professional development activities. The goal was to present younger members of the profession with alternative views of leadership. Johnson spoke about the characteristics of a leader and ways of acquiring leadership roles. Batie talked about different leadership styles and gender differences. Chicoine emphasized the difference between leadership and management, and inspiration as an element of exceptional leadership. Offutt talked about how government differs from academe and how good leaders may be poor managers. One issue raised during audience discussion was how leadership in departmental matters is rewarded. Other issues discussed were how leaders manage stress, and whether female leaders are evaluated more harshly than male leaders.

The Circle of Poison: Seeking a Solution. Stan Daberkow, organizer (ERS USDA), Otto Doering, moderator (Purdue University), Sandra Marquardt (Greenpeace), Bruce Buckland (National Agricultural Chemicals Association), Reed Benson (Environmental Protection Agency)
Legislation has been proposed in the U.S. to ban the export of unregistered pesticides. The objective of the proposal is to reduce pesticide-related risks in foreign countries, improve the safety of our imported food supply, and eliminate the potential of unfair competition for U.S. farmers. Marquardt stated that the U.S. exports millions of pounds of pesticides which are too toxic for use in the U.S. but are used in foreign countries, thereby exposing humans and their environment to these dangerous substances. Marquardt discussed the role the U.S. and other countries could play in reducing or eliminating pesticide poisonings and at the same time improving the safety of our imported food supply. Buckland presented the pesticide industry perspective on pesticide export legislation, emphasizing their concerns with the unilateral approach to a worldwide problem and the assumption that all unregistered pesticides exported from the U.S. represented a human health or environmental threat. Benson articulated the current administration's position on pesticide exports and examined the merits of various proposals to curtail the "circle of poison" from a federal agency viewpoint.

Groundwater Quality: New Mandates for Economic Education and Research. Harry Ayer, presiding (University of Arizona), Jeanne Briskin, (Environmental Protection Agency), Andrew Klein (Monsanto Agricultural Company), David Ervin and Marc Ribaudo (Oregon State University and ERS USDA), and Stanley Johnson (Iowa State University)
Groundwater quality is one of the most pressing perceived problems affecting agriculture and households. This session examined the new EPA and Monsanto water quality well studies and new and upcoming state and federal groundwater legislation and then drew implications for economic research and education. Briskin described the recent EPA National Survey of Pesticides in Drinking Water Wells and highlighted the need for across-the-board activities to reduce contamination of drinking water wells by pesticides and nitrates. She also concluded, based on the EPA study, that low-input agriculture may be an effective means to protect groundwater. Klein focused on Monsanto's recent National Alachlor Well Water Survey and the regulatory history, protocol development, study implementation, and scientific results. He concluded with the importance of nonregulatory programs, new research directions to pursue, and the economic effects of new regulatory programs on agriculture. Ribaudo and Ervin described the current and upcoming federal legislation to improve groundwater quality and the need for USDA and other agencies to expand research on different water quality strategies including low-input agriculture. Johnson summarized the current state legislation to maintain or improve groundwater quality, and the role of research and extension in the new legislation.

Foreign Direct Investment in U.S. Agribusiness: How Important Is It? Christine Bolling, presiding (USDA); David Stallings, Charles Handy, and Peter deBraal (USDA)
Foreign direct investment (FDI) in U.S. agribusiness increased from $22 billion in 1986 to $36 billion in 1989. The United Kingdom led in FDI in U.S. agribusiness, and Canada led in FDI in agricultural land. Others, like Japan, started from a low base and rapidly increased their holdings during the late 1980s. Macroeconomic events such as the weakening of the U.S. dollar and the large increase in investment money in Western Europe, Canada, and Japan, liberalizing trade agreements like the U.S.-Japan Beef and Citrus Understanding, and expansion of multinational companies made foreign direct investment in U.S. agribusiness an economically attractive alternative for foreign investors during the late 1980s. This symposium focused on the growth of foreign direct investment in U.S. agribusiness, the reasons for its occurrence at this time and the advantages and disadvantages of FDI for U.S. agribusiness. Stallings summarized the basic theory of foreign direct investment. Handy discussed recent trends in FDI in the U.S. food industry; deBraal noted recent developments in foreign purchases of U.S. agricultural land. Finally, Bolling cited trends in Japan's FDI in U.S. agribusiness and the reasons for the recent increase.

The Future of Rural America. Lyle Schertz, presiding (*CHOICES* editor), Judith I. Stallmann (Virginia Tech), Jill H. Findeis (Pennsylvania State University), Janet Perry (ERS ARED USDA), Christina H. Gladwin (University of Florida)
Changes in rural areas during the 1980s reverse both long-run trends and short-run trends of the 1970s. Despite evidence of change, rural areas are often perceived to be static, resulting in rural policy recommendations more appropriate for a previous time. State case studies document rural jobs, income, poverty, and quality of life. The gap between rural and urban areas in employment and income widened during the 1980s. Virginia's rural families respond to these trends with moonlighting, self-employment, and multiple earners. One trend that continued during the 1980s was the increasing number of farm families with nonfarm sources of income. National data documents the impacts of farm and off-farm income on income inequality among farm families. Lack of growth in jobs and income increased poverty in rural areas. A study of Pennsylvania rural families in poverty documents the incidence of short-term and long-term poverty. During the 1970s, rural areas were perceived as more attractive places to live than urban areas. Since then, the quality of life in rural Florida is perceived to have fallen. A perceived lower quality of life may decrease the ability of rural areas to attract and to hold residents.

Selected Papers

Commodity Futures: Option Pricing and Trade Strategies (Raj K. Chhikara, Iowa State University, presiding)

"A Reexamination of Helmuth's Trading Strategy for Live Cattle Futures." Emmett Elam and Chaw Wayoopagtr (Texas Tech University)
Helmuth introduced a trading strategy for live cattle futures that was very accurate in predicting price drops during 1978–81. The strategy was to sell futures when the price reached the USDA breakeven level plus a basis adjustment. In simulated trading from 1981–89, a significant risk-adjusted profit was made.

"Hedge Ratios in the Presence of Heteroskedasticity." Kenneth H. Mathews, Jr. (ERS CED USDA) and Paul L. Fackler (North Carolina State University)
The first two moments of cash and futures prices changes are modeled, and heteroskedasticity is demonstrated for steers, cows, and hogs. Hedge ratios, calculated within this heteroskedastic framework, are found to fluctuate randomly around means for steers and hogs but are nonconstant for a cow cross hedge.

"Pricing Commodity Options When the Underlying Futures Price Exhibits Time-Varying Volatility." Robert J. Myers and Steven D. Hanson (Michigan State University)
This paper outlines a model for pricing options when the underlying futures price exhibits time-varying volatility. Futures price movements are characterized using a GARCH model. In an empirical application, the GARCH option-pricing model predicts market premiums significantly better than the standard Black model, which assumes volatility is constant.

"An Investigation of Pricing Models for Live Cattle Futures Options." Robert A. Pelly (Partners National Health Plans), Scott A. Irwin and Carl R. Zulauf (Ohio State University)
Black's European model predicts premiums for live cattle futures options as accurately as Barone-Adesi and Whaley's American model. Implied volatility estimators generate more accurate forecasts of actual option premia than historical volatility. Bias regression results are consistent with accuracy tests. Only implied volatility-based models exhibit market-timing ability.

Impacts of Depreciation, Taxes, and Consumer Installment Debt (Greg Hanson, Pennsylvania State University, presiding)

"Depreciable Asset Pricing Under Rationality: A Test on Combine Purchases." Gary Schnitkey (Ohio State University)
We examine asset replacement assuming that used asset prices are determined rationally. We test the theory on combined purchases. Results suggest that used asset prices may be determined rationally; however, the relationship between the new price and used prices is not explained by rational pricing.

"A Comparison of Federal Taxes Paid by the Farm and Nonfarm Sectors." Patricia A. Duffy, Henry W. Kinnucan, and Robert Pendergrass (Auburn University)
In this study, we used Internal Revenue Service data to compare the effective federal tax rates of farming versus nonfarming taxpayers. We found taxes paid to be comparable across sectors for high-income taxpayers. We also found the far sector to have slightly more progressive federal taxes than the nonfarm sector.

"Impact of Consumer Installment Debt on Food Expenditures." Raymond Kirby and Oral Capps, Jr. (Texas A&M University)
Trends in consumer installment credit over the period 1966–88 are discussed to identify and assess the impact of installment credit on food expenditures. Two measures of installment credit, installment credit as percent of disposable income and as percent of total assets, are used to test appropriate hypotheses.

Assessment of Risk and Returns in Agriculture (Bruce Ahrendsen, University of Arkansas, presiding)

"Reliability of Soybean and Corn Option-Based Probability Assessments as Option Markets Mature." Elvira Silva and Kandice H. Kahl (Clemson University)
The objective of this paper is to determine whether option-based probability assessments become reliable through time. The reliability of soybean and corn option-based probability assessments is evaluated 1985–87 and 1988–90. Soybean probability assessments become reliable 1988–90. Corn probability assessments are reliable in both time periods.

"An Empirical Investigation of Systematic Risk in Agribusiness." Richard N. Weldon, Charles B. Moss and Reginald Blackman (University of Florida)
Historically, agriculture has seen several bouts of financial prosperity and stress which have also affected

agribusiness. This paper examines whether the variability surrounding agriculture and agribusiness has caused significant risk premia associated with agricultural stocks above what would normally accrue.

"An Examination of Farm Real Estate Return Definitions, Inflationary Effects, and the Riskiness of Nonland Farm Equity." Lynn H. Miller and Bruce J. Sherrick (University of Illinois)
Analyses of agricultural real estate under alternate return definitions find returns that offer market investment premiums, may hedge positive beta asset returns, and exhibit unexpected inflation premiums. The assumption of a zero-beta return to non-real estate equity is not robust and CAPMUEI is superior to the CAPMUI specification.

Financing Agriculture (Calum G. Turvey, University of Guelph, presiding)

"Membership Size and Funds Mobilization among Informal Financial Groups in Rural Zaire: A Club Theory Approach." Curtis H. Slover and Carlos E. Cuevas (Ohio State University)
A formal model of informal financial groups is developed. A system of equations is estimated by a two-stage method to evaluate key characteristics of the organizational form of informal financial groups in Zaire. Income, transaction costs, and gender ratio were found to be some of the significant explanatory variables.

"Financing of Growth in Agricultural Cooperatives." Zvi Lerman (Hebrew University) and Claudia Parliament (University of Minnesota)
Flows of funds in agricultural cooperatives are examined and compared to all nonfinancial corporations. Contrary to the hypothesis of equity shortage, cooperatives finance nearly half their growth and equity. Although this proportion is lower than the national average, the difference does not unambiguously support the hypothesis of equity bound cooperatives.

"Are Rural Commercial Banks Really More Efficient Than Agricultural Development Banks? New Evidence from Bangladesh." M. A. Baqui Khalily, Richard L. Meyer, Leroy J. Hushak, and Carlos E. Cuevas (Ohio State University)
This paper presents an analysis of the relative economic efficiency of rural commercial and development banks in Bangladesh using a normalized profit function. Contrary to the experiences to other developing countries, the development banks are relatively more technical and price efficient in producing loans than commercial banks.

"Geographic Deregulation of North Dakota's Commercial Banks." Peter Solemsaas and Cole Gustafson (North Dakota State University)
Bank branching potential is gauged with a correlation-decomposition model using 1976–87 Call Report data. One-fourth of possible bank mergers in North Dakota could yield diversification benefits. Bank characteristics most important to merger include size, loan portfolio diversity, loan pricing strategies, service income, and liability management practices.

Information and Futures Prices (Catherine Lemieux, Federal Reserve Bank, Kansas City MO, presiding)

"Impact of Cash Settlement on Basis Variation for Soybean Futures Contracts." Julien S. Lee and Lee F. Schrader (Purdue University)
The impact on basis variation of a change to cash settlement of soybean futures based on USDA Grain and Feed Market News quotations is investigated. Potential for reduction in basis variability with cash settlement is demonstrated assuming that cash settle futures prices parallel the cash index at contract expiration.

"USDA Export Sales Report: Is It News?" Paul M. Patterson and B. Wade Brorsen (Purdue University)
This paper investigates whether the U.S. Export Sales report provides new information to the market. Event study methodology is used to evaluate the movement of futures prices on days around the release of the report. The results reveal that the information in the report is generally anticipated by traders.

"The Role of Futures in Daily Forward Pricing." Ted Covey (ERS USDA) and David A. Bessler (Texas A&M University)
The addition of the nearby settle price for live cattle futures to the information set of a time-series model significantly improved post-sample predictions of daily fed cattle cash prices. We concluded that futures could have contributed to daily forward-pricing of Texas-Oklahoma slaughter cattle during 1988.

"Futures Market Reaction to Cattle on Feed Reports." Orlen Grunewald, Mark S. McNulty, and Arlo W. Biere (Kansas State University)
This paper is an application of efficient markets–rational expectations theory to analyze empirically the relationship between *Cattle on Feed* reports and changes in cattle futures prices. The results show that inventory and marketing information is absorbed efficiently in futures prices while placements information is absorbed only partially.

Natural Resources Models and Methods (Alan Collins, West Virginia University, presiding)

"Estimating the Precision on Welfare Measures." Catherine L. Kling (University of California, Davis)

Three methods of constructing standard errors of welfare estimates have been employed in the recreation demand literature: a Taylor's-series approximation, the bootstrap, and a method proposed by Krinsky and Robb. This paper presents the results of a simulation experiment designed to examine the accuracy of these methods.

"Externalities, Uncertainty, and Compensation for Crop Damage from Wildlife: A Principal-Agent Approach." Kimberly S. Rollins and Richard C. Bishop (University of Wisconsin)
A theoretical model based on principal-agency theory provides fresh ideas for addressing the problem of crop damage from wildlife. Principles for a program that would better recognize the nature of the crop damage externality are derived. Uncertainty about important biological and economic parameters is explicitly addressed.

"Model Misspecification Bias in the Estimation of Ricker Stock-Recruitment Models." Neal S. Johnson (University of Washington)
As traditionally specified, the Ricker stock-recruitment curve has an implicit parameter restriction which, if incorrect, will lead to biased coefficient estimates and possibly erroneous conclusions regarding the presence or absence of density-dependent mortality in fisheries. The bias and a methodology remedy are discussed.

Empirical Studies in Natural Resources (Michelle C. Marra, University of Maine, presiding)

"Tropical Deforestation and Agricultural Development in Latin America." Douglas Southgate (Ohio State University)
This paper contains a regression analysis of the causes of agricultural colonization in twenty-three Latin American countries. Yield growth, associated with increased supplies of non-land inputs to crop and livestock production, is found to alleviate the pressure for frontier expansion induced by enhanced demand for agricultural commodities.

"Classical Biological Control of Insects: A Benefit Cost Approach." Michael H. Habeck, Stephen B. Lovejoy, and John G. Lee (Purdue University)
A simple benefit-cost framework suggests that we are seriously underinvesting in classical biological control (CBC) research. The analysis shows minor costs and the potential for major benefits. Because the benefits of CBC research are widespread and difficult to assign, such research should be funded from general government revenues.

"Rainfed Mechanized Farming and Deforestation: Empirical Evidence from Sudan." Daniel W. Bromley (University of Wisconsin) and Abdelmoneim H. Elnagheeb (University of Georgia)
We addressed the question: Why farmers in rainfed mechanized schemes of Sudan do not leave shelterbelts. Results indicate that farm size, a farmer's belief in shelterbelts' benefits, type of farm ownership, gum arabic production, wealth, and years a farmer has been cultivating farm are factors that influence a farmer's decision on shelterbelts.

"Economic Analysis of a Municipal Recycling Program." Donna J. Stucky and Wallace E. Tyner (Purdue University)
This paper provides an economic evaluation of five alternative waste disposal programs for a small municipality in Indiana. The results indicate that recycling and composting can be cost effective with careful program design and that recycling become more attractive as landfill tipping fees and recycled material prices rise.

Natural Resources Issues in Agricultural Production (Wallace E. Tyner, Purdue University, presiding)

"Soil Conservation Benefits of Sustainable Cropping Systems." Tony Prato and Shunxiang Wu (University of Missouri)
Effects of sustainable cropping systems on erosion damages and farm income are evaluated for an agricultural watershed. Erosion damages did not influence the efficient choice of cropping systems or the optimal level of sediment control. Sustainable cropping systems substantially reduced erosion damages and increased farm income relative to historical systems.

"Effects of Environmental Policy on Trade-Offs in Weed Control Management." Aziz Bouzaher, David Archer (Iowa State University), Richard Cabe (New Mexico State University), Alicia Carriquiry, and Jason F. Shogren (Iowa State University)
This paper presents a novel approach for generating information for regulatory and policy analysis, based on farmers' adoption of weed control technology. A simulation model, WISH, is used to generate cost and risk information on 258 weed control strategies. Environmental policies simulated are bans on triazines and broadcast application technology.

"Nonpoint Source Pollution Control in a Diverse Agricultural Setting: A Biophysical Simulation Approach." Michael L. Taylor (Oregon State University)
This paper examines economic incentives to offset non-point source pollution from agriculture. A biophysical simulator to estimate technical relationships

is linked to linear programming models for representative farms in the Willamette Valley of Oregon. The results indicate site-specific conditions greatly influence policy effectiveness.

"A Sample of CRP Contract Holders on Future Land Use." M. J. Monson and Robert Lenkner (University of Missouri)
Over 1,700 CRP participants in Missouri were surveyed regarding future land use intentions and conservation practices, along with demographic characteristics. Results indicate that nearly 50% of CRP land will return to crop production when contracts expire and 30% will be used for pasture or hay.

Rural Economic Development Issues (G. Andrew Bernat, Jr., ARED HRIB ERS USDA, presiding)

"An Analysis of Retail Sales Leakages from an Insular Economy." Bernard K. Chan (Financial Analyst, Bishop Estate), John F. Yanagida, Hiroshi Yamauchi, and PingSun Leung (University of Hawaii)
This study attempts to quantify and explain retail sales leakages from counties in the state of Hawaii. Results suggest that Hawaii's retail activities are diffuse and spread throughout each county without any significant central place tendencies. These results from an insular economy are quite different as compared to earlier studies.

"New or Expanding Basic Sector Firms in the Upper Great Plains: Employment Creation and Economic Linkages." Larry F. Leistritz (North Dakota State University)
The purpose of this study was to identify new or growing basic sector businesses in Nebraska, North Dakota, and South Dakota and to determine their contribution to the state economy, as measured by their employment creation and their expenditures to suppliers within the state. Data from 314 firms were used in the analysis.

"A Test of the Employer Size-Wage Relationship: Implications for Rural Development Policy." David S. Kraybill, Michael J. Yoder (University of Georgia), and Kevin T. McNamara (Purdue University)
Recent rural development policies emphasize small business development. To analyze likely effects of this policy focus, we estimate an empirical wage rate model using rural household data. Results show that larger employers offer systemically higher wages. Education and job tenure are also positively related to wage rates.

Applications of Input-Output Analysis (David L. Darling, Jr., Kansas State University, presiding)

"Economic Structure and Income Redistribution: An Input-Output Perspective." G. Andrew Bernat, Jr. (ERS USDA)
This paper presents a method of analyzing the distributional impacts of changes in sectoral output using an extended input-output model. An application of this method to a small resource-based region demonstrates that the distributional impacts of changes in sectoral output vary a great deal across sectors.

"Community Impacts: The Case of the Conservation Reserve Program." David A. Henderson (ERS ARED USDA), Luther G. Tweeten (Ohio State University), and Mike Woods (Oklahoma State University)
Retail sales are analyzed for three sizes of community in the Southern High Plains. The results suggest consumer spending from personal farm income vary by size of community and source of income. The results have implications for estimating community retail impacts from income shocks caused by the Conservation Reserve Program.

"Regional Economic Impacts of Recreation Visitation Response to Reservoir Water Level Management." Donald B. K. English, John C. Bergstrom (University of Georgia), and H. Ken Cordell (Forest Service USDA)
The economic impacts of delaying summer water drawdown at four North Carolina reservoirs are examined. Visitor surveys collected expenditure information and anticipated visitation increases. Results indicate visitation is responsive to management policy. A two-month delay doubles recreation's current economic contribution. Growth largely accrues from reservoirs most developed for recreation.

Regional Economics (Kevin McNamara, Purdue University, presiding)

"Value Added—A New Approach to Measuring the Income Produced by Agriculture." John E. Jinkins (ERS USDA)
This paper proposes a framework for measuring agricultural value added and explores variations in value-added creation among farm types. Results show that crop farms usually generate more value added per dollar of farm income than livestock operations. Grain farms had ratios of value added to farm income almost as great as farms specializing in higher-priced commodities.

"Falling Transport Costs and Agricultural Development: Implications of Von Thuenen's Model of the Dual Economy." Efraim Sadka (Tel Aviv University) and Marc Nerlove (University of Pennsylvania)
Von Thuenen's general equilibrium model of the dual economy shows that falling transport costs alone are

sufficient to induce a movement of labor from the rural/agricultural to the urban/industrial sector. More rapid rural population growth or higher income elasticities of demand for manufactures are not necessary.

"Theocratic Stabilization of Agricultural Commodity Markets in the Great Basin, 1847–1900." L. Dwight Israelsen (Utah State University)
The use of uniform tithing prices as a method of stabilizing agricultural commodity markets in the Great Basin is examined. It is found that the method was successful in stabilizing prices and available supplies of staple commodities, but that the stabilization policies became less effective as the century progressed.

Off-Farm Employment in Rural Economies (Thomas R. Harris, University of Nevada, Reno, presiding)

"An Analysis of the Off-Farm Work Decision of Farm Operators and Their Spouses." Steven E. Hastings, John MacKenzie, and Jaideep Mukherjee (University of Delaware)
Off-farm work by farm operators and their spouses continues to be an important and stabilizing source of income. This paper models that joint off-farm work decision of farm operators and their spouses using bivariate probit analysis. Implications for rural economic development policy are discussed.

"An Application of the Probit Model to the Decision to Farm." Janet E. Perry (ERS ARED USDA)
Maximum likelihood estimation of a probit model is conducted to test the influence on the decision to farm of the expected earnings differential between farm and nonfarm employment. Results are that young men seek a comparative advantage when deciding on employment.

"The Impact of Nonfarm Activity on Income in a Philippine Upland Village." Julie P. Leones, University of Arizona
Decomposition of the concentration coefficient of income distribution and examination of households' income structure in a Philippine village indicate that the poorest households are not benefiting proportionally as much from nonfarm income as wealthier households. However, some types of nonfarm income may reduce inequality caused by landholding differences.

"Estimating State- and County-Level Demands for Educational Attainment." David L. Debertin and Stephan J. Goetz (University of Kentucky)
A procedure is developed based on "step-down" methods familiar from input-output studies to estimate county-level demands for educational attainment. An empirical example is presented. Potential applications are numerous, including rural labor market studies designed to evaluate opportunities for farmers seeking off-farm employment.

Issues in Chinese Agriculture (Gail Cramer, University of Arkansas, presiding)

Quantifying the Relative Importance of Village Leaders in China's Reform Economy." Scott Rozelle (Stanford University) and Richard N. Boisvert (Cornell University)
Using village-level data, parameters of a control model containing a multiattribute utility function are estimated econometrically to quantify the relative importance of leaders' various objectives. The results suggest that leaders are preoccupied with rural industrialization to further personal gain and independence from higher authorities. They are concerned about village welfare and maintaining agricultural productivity.

"The Impact of China's Grain Policy on Provincial Wheat Production: Implication for Trade." Shwu-Eng H. Webb (ERS USDA) and Catherine Halbrendt (University of Delaware)
Provincial crop production, acreage and price data for 1979–88 are used to estimate China's provincial wheat production functions. Prices have little effect on land use, but they affect the allocation of variable inputs, thus, affect yield and production. The paper estimates the impacts on provincial wheat production of trade liberalization.

"Grain Policy in China's Provinces Simulating the Response of Grain Yields to Price, Procurement and Credit Policies." Scott Rozelle (Stanford University) and Richard N. Boisvert (Cornell University)
This paper assesses the effects of pricing, procurement, and loan policies on China's grain economy. A dynamic control model of the village leader is specified. Simulation results show that pricing and procurement policies are not effective in raising yields due to conflicting objectives of officials. Loan policies increase yields.

"Targeting Transaction Costs: An Evaluation of Investment Incentive Policies in China." Yvonne Wang Yuen Ying (International Food Policy Research Institute), Scott Rozelle, and Melinda Barlow (Stanford University)
This paper explores the effectiveness of incentive policies in attracting foreign investment in China. In a transaction cost-minimization conceptual framework, cross-section data from 132 cities are used for testing the hypothesis that transaction cost-reducing policies are more effective than other incentive policies. The hypothesis is validated.

Technology Adoption and Productivity in Developing Economies (Lydia Zepeda, University of Wisconsin, presiding)

"The Effect of Animal Traction on Labor Productivity and Food Self-Sufficiency: The Case of Mali." Curtis M. Jolly (Auburn University) and Millie A. Gadbois (Readings University, London)
Effects of animal traction (AT) on labor productivity and food self-sufficiency were analyzed, using regression and logistic models. AT uses increased area planted and crop production but had no effect on area planted per labor unit nor food self-sufficiency. If AT enhanced labor productivity, it increased the probability of attaining food self-sufficiency.

"Farm Size and Land Use Intensity in Indian Agriculture." R. K. Sampath (Colorado State University)
Using India data, this paper critically evaluates the validity of the popular hypothesis, namely, the inverse relationship between farm size and land use intensity. It argues that the diseconomies of scale in land use observed in the past could have resulted from the narrow definition of farmsize with no distinction made between irrigated and unirrigated lands.

"Are We Underinvesting in Research for Marginal Environments? The Example of Wheat in Developing Countries." Derek Byerlee and Michael L. Morris (International Maize and Wheat Improvement Center)
A simple congruency model is used to examine the case for shifting research resources from favored to marginal environments, with particular reference to wheat breeding. Preliminary analysis suggests that research resources invested in marginal environments of LDCs have been roughly proportional to the weighted value of wheat production in these environments.

"Technology Transfer, Contract Structure, and Incentives for Further Information." Bruce A. Larson and Margot Anderson (ERS RTD USDA)
A principal-agent model is used to analyze how risk preferences, expectations about indigenous innovation possibilities, and asymmetric information alter technology payments and the incentives for further domestic innovation. Higher risk aversion reduces buyer incentives to innovate. Technology buyers are generally better off when the seller cannot anticipate further innovation.

"Assessing the Effects of a Development Project on Small Farm Production and Marketing Efficiencies." Melanie L. Roof and John Mackenzie (University of Delaware)
A stochastic iso-revenue frontier model is outlined and used to estimate both production and marketing efficiency indices. An empirical application analyzes the efficiencies of small farms in Guatemala and examines the effects of a technical assistance project on those efficiencies.

Impacts of Price Stabilization Policies in Developing Economies (John MacKenzie, University of Delaware, presiding)

"Prices and Productivity in Agriculture." Lilyan E. Fulginiti (Iowa State University) and Richard K. Perrin (North Carolina State University)
An aggregate agricultural production function with variable coefficients is estimated for eighteen LDCs to show that government policies that affect past price expectations have an impact on the choice of technology to implement and consequently reduce factor productivity.

"Commodity Price Stabilization in a Peasant Economy." Israel Finkelshtain (Hebrew University) and James A. Chalfant (University of California, Berkeley)
Three mechanisms of complete and partial price stabilization are contrasted. For a typical peasant household, complete price stabilization dominates partial price stabilization in the consumption sector but is dominated by partial stabilization in the production sector.

"Indian Agricultural Price Policy Revisited." David G. Abler (Pennsylvania State University) and Vasant Sukhatme (Macalester College)
Indian agricultural price policy discriminates against farmers in favor of consumers. This paper criticizes two common defenses: First, prices may affect supply but infrastructure is more important; second, policy is a form of price discrimination that helps producers. This paper also simulates the effects of different policy regimes.

"Farmer Response to Price Incentives Under Risk: The Case of Inland Wolof Farmers in Eastern Gambia." Mohamed B. Kebbeh (Department of Research, The Gambia) and Lydia Zepeda (University of Wisconsin)
To understand how prices set by the Gambian Producer Marketing Board affect production decisions, optimum cropping decisions are simulated given different resource endowments, weather, and risk preferences. Accounting for risk indicates response to pricing policy is minimal. Improving yield stability and labor productivity have a greater effect on farm income.

Effects of Domestic Agricultural Policies on World Trade (Timothy Park, University of Nebraska, presiding)

"Reforming Agricultural Policies in Japan: Effects on World Markets." Praveen M. Dixit and Vernon O. Roningen (ERS USDA)
The world trade model used for this study suggests that Japanese agricultural policies have depressed world rice prices substantially. The study also indicates that if the rice market were to be differentiated into indica and japonica varieties, price increases from liberalization would be smaller for the former than the latter.

"A Game-Theoretic Analysis of the Australian Tobacco Domestic Content Policy." John Beghin and Daniel Sumner (North Carolina State University)
The paper develops a cooperative game-theoretic model to analyze physical content requirement and market policies in the Australian tobacco and cigarette industry. Welfare and trade effects are analyzed. The paper also suggests empirically testable hypotheses on the production, welfare, and trade effects of these policies.

"Market Interventions, International Price Stabilization, and Welfare Implications." S. Devadoss (Iowa State University)
The welfare effects of price stabilization are quantified under free trade and under distortionary policies when an exporting country implements price supports, an importing country imposes variable import levy, and a second importing country follows free trade. The results show that world trade can be increased by stabilizing the international prices.

"U.S. Wheat Price Dynamics and the Export Enhancement Program." D. Demcey Johnson, Seung-Ryong Yang, and Won W. Koo (North Dakota State University)
This paper examines the effects of EEP on U.S. wheat price dynamics using the GARCH models. The results showed that EEP has significant effects on the volatility of the Gulf and farm prices, although the effects on price levels are mixed. The farm price level is not significantly affected by the program.

Impacts of Agricultural Trade Liberalization on Domestic Agriculture (Mary Marchant, University of Kentucky, presiding)

"Milk Quota Prices and Expectations of Trade Liberalization." Bruno Larue and James Oxley (University of Guelph)
This paper assesses expectations of trade liberalization on the value of milk quota in Canada. A capitalization model with adaptive expectations about net returns is developed. Statistical tests indicate that by 1986 the Canadian–U.S. Trade Agreement and GATT negotiations would influence Canadian dairy policy.

"Textile Trade Liberalization and the U.S. Cotton Industry." Shangnan Shui and John Beghin (North Carolina State University)
This study investigates impacts on the U.S. cotton industry of textile trade liberalization using a multimarket equilibrium displacement model. Textile trade liberalization would induce small changes in the total demand for U.S. cotton but would affect considerably U.S. cotton demand structure, making U.S. cotton growers more dependent on world markets.

"Impacts of Subsidy Removal and Trade Liberalization of Feed Ingredients in Tunisia." Patricia Kristjanson (ABT Associates) and Wallace E. Tyner (Purdue University)
This article summarizes a recent agricultural policy study examining the impacts of trade liberalization and removal of feed ingredient subsidies in Tunisia. A linear programming model was used to simulate private sector response to these policy changes, and options regarding the timing and sequence of policy reforms were explored.

"Trade Effects of U.S.–Mexico Harmonization of Pesticide Regulations." Martin A. Johnson and Ann Hillberg Seitzinger (ERS ATAD USDA)
Prospects of a free trade agreement between the United States and Mexico have brought calls for harmonizing the two countries' pesticide regulations. Research finds that harmonization of U.S. and Mexican pesticide regulations may increase or decrease U.S. imports; the direction of change depends on current regulations.

Economic Issues in International Agricultural Trade (Thomas Wahl, Washington State University, presiding)

"An Assessment of Trade Statistics Reliability." Marinos E. Tsigas (The World Bank), Thomas W. Hertel and James K. Binkley (Purdue University)
The reliability of trade statistics is questionable because of unexplained discrepancies. This paper presents a methodology for quantifying the systematic component of such unreliability. The method is applied to U.N. data pertaining to OECD countries. It is found that some countries consistently over- or underreport trade.

"Measuring Agricultural Trade Distortions: A Simple Approach." Vernon O. Roningen and Praveen M. Dixit (USDA)
This paper points out the pitfalls of using aggregate measures of support as indices of trade distortion. It then presents a simple volume-based method of measuring and monitoring agricultural trade distortion. Empirical estimates indicate that high levels of support do not necessarily imply big trade distortions, even for a large country.

"Modeling Country Origin of Exported Soybeans in EC Destination Ports: A LOGIT Approach." Mildred M. Haley (Louisiana State University)
This study models country origins of exported soybeans at EC destination ports in a LOGIT framework, with quality characteristics as explanatory variables. Results indicate that shipments with low oil yield and high FM have a greater probability of being of U.S. origin than South American origin.

"Korea's Beef Market in a Pacific Context." Jeffrey W. Jones (FAS USDA) and John H. Dyck (ERS USDA)
Factors inside and outside of Korea have converged to make a substantial trade in beef likely. Within Korea, higher beef demand and limited supplies have resulted in high prices. Outside Korea, the experiences of Pacific Rim traders in the opening of Japan's market have lowered the cost of exporting beef.

"Tariffication of Imperfectly Competitive Import Markets: The Case of Japanese Beef Quotas." Brad C. Gehrke and Maury E. Bredahl (University of Missouri)
In the presence of nontariff trade restrictions, imperfectly competitive behavior by importers may be unobserved. It can be shown theoretically that conversion of these barriers to bound tariffs, without concurrent reduction of the imperfectly competitive behavior, would lead to unintended results from the tariffication process, the reduction of import access.

Domestic Economic Issues in Developing Countries (Stanley Fletcher, University of Georgia, presiding)

"Economics of Fertilizer Use in the Production of Sorghum in Botswana." Senye Matswe Kono (Ministry of Agriculture of Botswana) and Dale Colyer (West Virginia University)
Regression analyses of data from two studies indicate positive responses of sorghum yields to fertilizer in Botswana. Rainfall, however, has more effect on yields and raises questions about risk from increased use of purchased inputs, which may be the major factor in low fertilizer use in African dryland farming areas.

"Income Sources in Rural Gambia: The Role of Off-Farm Income." Cathy L. Jabara and Mattias K. A. Lundberg (Cornell Food and Nutrition Policy Program)
Analysis of household income data from rural Gambia indicates that income is determined by the availability of male labor, access to improved farming technology, and off-farm work. When most households have access to improved farming technology, a rural income strategy might concentrate on improving opportunities for off-farm employment.

"Determinants and Effects of Household Income Diversification by Agroecological Zone in the West African Semi-Arid Tropics." Thomas Reardon, Christopher Delgado (IFPRI), and Peter Matlon (WARDA)
Using four years of household data from three agroecological zones in Burkina Faso—Sahelian, Sudanian, and Guinean—the paper examines the determinants and effects of household income diversification. Harvest shortfalls and terms of trade are found to drive diversification, but land constraints are not. Income diversification is associated with higher income and food consumption.

"Public Good Provision and Trade Policies of a Developing Country." E. Kwan Choi (Iowa State University)
This paper investigates optimal tariff and provision of a public good in a small open economy that produces two traded goods and a single public good. Public production of the public good is socially preferable to private production unless the public good exhibits constant returns to scale.

Topics in International Trade and Developing Economies (Shwu-eng Webb, ERS ATAD USDA, presiding)

"Counter-Trade/Food Aid: Support and Enhancement of Structural Adjustment." Barry E. Prentice (University of Manitoba) and Fred J. Ruppel (Texas A&M University)
Although food aid has been advocated for countries undertaking structural adjustment policies, political support for increased aid expenditures is lacking. Counter trade is proposed herein as a method for expanding food aid without increasing expenditures. Counter trade allows developing countries to accelerate growth in their export sectors, while "financing" increased food assistance.

"Exchange Rate Distortions in International Agricultural Trade." Jaime E. Malaga and Fred J. Ruppel (Texas A&M University)
Many nations, particularly developing countries, overvalue their currencies. The relative importance of these exchange rate distortions in five developing countries, 1982–87, is assessed. Results indicate that overvalued currencies (in many cases) have completely offset positive rice and wheat sectoral and trade subsidies, on balance hurting agricultural producers in developing countries.

"The Impact of Real Exchange Rate Misalignment on Agricultural Exports and Macroeconomic Performance in Sub-Saharan Africa." Dhaneshwar Ghura and Thomas Grennes (North Carolina State University)

The study investigates the relationship between six indicators of economic performance and real exchange rate (RER) misalignment in Sub-Saharan Africa. The misalignment index is econometrically retrieved using pooled time-series/cross-section data for 33 countries 1970–87. The negative relationship between misalignment and economic performance is confirmed.

"Testing Two Trade Models in Latin American Agriculture." Carlos Arnade (ERS USDA)
This paper demonstrates that Latin American agricultural trade is consistent with both the Heckscher-Ohlin and Markusen proposition that countries export goods intensive in the use of their relatively abundant factor. The paper then shows this trade is explained by country differences in relative factor abundance rather than differences in technology.

Studies in Farm Management (Azzedine Azzam, University of Nebraska, presiding)

"Perceptions and Reality on Large-Scale Dairy Farms." Paul N. Wilson, Roger D. Dahlgran (University of Arizona), and Neilson C. Conklin (Arizona State University)
Recent psychological research supports the claim that decision makers respond to their perceptions of uncertainty in their business decisions. Using large-scale dairy operations as a case study, preliminary results indicate that operators of large, industrialized farms perceive their business environments in a unique manner and respond accordingly.

"Potential Regional Shifts in Milk Production." James W. Richardson, Joe L. Outlaw, Ronald D. Knutson, Robert B. Schwart, Jr. (Texas A&M University), and John Holt (University of Florida)
Previous studies of decisive regional shifts in milk production toward the west were evaluated utilizing updated representative farms. In all regions the economic advantages of large-scale farms was verified. Upper Midwest and New York farms indicated substantial resilience. However, the Vermont farms and the moderate Southeast farm lost equity.

"Risk Considerations in Crop Intensification vs. Crop Diversification for Eastern Corn Belt Farmers." Samuel A. Bruner (NASS), Craig L. Dobbins, and George F. Patrick (Purdue University)
Irrigated corn and processing cucumbers are analyzed as alternative enterprises. Irrigated corn with 45 and 60 bushel yield increases provided higher income and lower variability for both debt-level farms. Results were less favorable with the 30 bushel corn yield increase and cucumber alternatives. Initial financial position was important when comparing cucumber alternatives.

"Area Measured Crop Insurance and Disaster Aid for Wheat and Grain Sorghum." Jeffrey R. Williams, Gordon L. Carriker, G. Art Barnaby (Kansas State University), Jayson K. Harper (Pennsylvania State University), and J. Roy Black (Michigan State University)
Area crop insurance and disaster aid program designs are compared to an individual farm-yield insurance design like the current FCIC multiple peril program. Stochastic dominance analysis of net return distributions for 45 wheat and grain sorghum farms in south central Kansas is used to determine which strategy is preferred.

Nonparametric Production Analysis (Gary D. Thompson, University of Arizona, presiding)

"A Nonparametric Analysis of the Influence of Research on Agricultural Productivity." Jean-Paul Chavas and Thomas L. Cox (University of Wisconsin)
Nonparametric productivity analysis is extended by endogenizing technical change as a function of public and private research expenditures. Results indicate that 30 years of lags are required to capture the effects of public research expenditures on U.S. agricultural productivity. Associated internal rates of return are found comparable to previous estimates.

"A Nonparametric Analysis of Cost Minimization and Profit Maximization Behavior for a Sample of Kansas Farms." Ghassan A. Moghnieh, Allen M. Featherstone, and Barry K. Goodwin (Kansas State University)
This study investigates nonparametrically the optimizing behavior of a sample of 363 Kansas farms under profit-maximizing and cost-minimizing hypotheses. The results do not support strict adherence to either optimization hypothesis. However, evidence against cost-minimizing behavior seems to be far less substantial than that against profit-maximizing behavior.

"Alternative Environmental Policies and Input Substitution in the Corn Belt: Implications of Environmental Policy." Daniel Primant (Southern Illinois University), Richard Nehring, and Agapi Somwaru (ERS USDA)
This study investigates the impact on input substitution and profitability of production in corn farming of various agricultural chemical regulatory policies. Data on corn production are used to estimate a nonparametric model of profit maximization. Results indicate a triazine ban causes the greatest decrease in farm profitability.

Empirical Cost and Profit Functions (Giancarlo Moschini, Iowa State University, presiding)

"The Effect of Input Policy on Cost of Production of Wheat in the U.S. and the U.K." Roberto J. Garcia and Alan Randall (Ohio State University)
Input policies, a tax and a quantitative restriction on fertilizer, are analyzed in terms of changes in the cost of wheat production in the U.S. and the U.K. Input price and quantity elasticities of supply are computed for both countries for comparison of potential agri-environmental policy to reduce fertilizer use.

"Factor Demands in the U.S. Food-Manufacturing Industry." Kuo S. Huang (ERS USDA)
This paper analyzes the demand for labor, capital, and energy in the U.S. food-manufacturing industry using Allen and Morishima elasticities of substitution. The demand for capital is more elastic than for labor and energy, and these production factors are substitutable, especially between capital and labor.

"Calculating Profit-Neutral Land and Price Policies." Sandra Grigsby (AID) and Carlos Arnade (ERS USDA)
This paper shows that introduction (or removal) of land set aside and government price supports can be coordinated so that they do not change the profits of agricultural producers. A profit function is estimated for a subsector of Brazilian agriculture and used to simulate profit-neutral changes in land used and output prices.

"Multiproduct Scale and Scope Economies for Agricultural Cooperatives." Ted C. Schroeder (Kansas State University)
This study estimates scale and scope economies for multiproduct farm supply and grain marketing local cooperatives. Bootstrapping regressions are used to estimate confidence intervals. Product-specific scale economies exist for grain, petroleum, feed, and other merchandise, and to some extent fertilizer. Scope economies are present for six products.

Farming Systems (Joy L. Clark, Auburn University, presiding)

"Economic and Environmental Implications of Alfalfa-Based Cropping Systems." John G. Lee, John C. Foltz, and Marshall A. Martin (Purdue University)
Farmers and policy makers are interested in analyzing the economic and environmental trade-offs associated with alternative farming systems. Including alfalfa in an Eastern Corn Belt cropping system can reduce soil erosion and improve surface water quality. However, net returns are reduced, and these systems have the potential of increasing nitrates in groundwater.

"Potential Effects on Rural Economies of Conversion to Sustainable Farming Systems." Thomas L. Dobbs and John D. Cole (South Dakota State University)
An examination of potential effects on local rural economies of a conversion from conventional to sustainable farming systems and practices. Case study conventional and sustainable farms in five agroclimatic areas of South Dakota were used to generate data for quantitative analyses of back- and forward-linked impacts.

"Alternative Methods for Soil Conservation to Comply with the Conservation Compliance Program." Ramu Govindasamy and Michael Duffy (Iowa State University)
Net returns were analyzed with restrictions that soil erosion could not exceed 7 tons per acre. The choice mulch-strip-ridge till was optimal in all 12 major soils analyzed. The optimal management technique in 11 of the 12 soils uses no management technique with a P factor of one.

"The Effect of Off-Farm Employment and Stage in the Life Cycle on the Woman's Role in Farm Task Participation and Decision Making." Rebecca Lafferty and Burton Pflueger (South Dakota State University)
In this paper, we investigated the woman's role in farm task participation and decision making based on stage of the lifecycle and off-farm employment status. The results from the 1990 South Dakota Farm Woman survey are analyzed to determine the woman's role and suggest possible reasons for the variation.

Chemicals in Agriculture (Bruce A. Babcock, Iowa State University, presiding)

"Estimating Applied Nitrogen Equivalents with a Generalized Linear Response and Plateau Function." Matthew F. Spilker (ERS RTD USDA)
The linear response and plateau function is modified to account for cross-sectional variability in factors of production. Marginal yield response to nitrogen is estimated, by nitrogen source, for Nebraska irrigated corn. The observed source differences have implications for firm profitability when soil testing is used to adjust application rates.

"Managing Nitrogen Fertilizer Under Different Soil and Weather Conditions." Qi Dai, John G. Lee (Purdue University), and Jerald J. Fletcher (West Virginia University)
A generalized nitrogen decision model is developed to determine nitrogen recommendations for corn under different soil and weather conditions. Optimal nitrogen rates depend on soil and weather and assumed specification of production technology. The economic cost of applying an optimal recommendation to a different soil could be as high as $43 per acre.

"The Effect of Alternative Farming Practices on Reducing Excessive Nitrogen Fertilizer Use." Wen-Yuan Huang and Noel D. Uri (ERS USDA)
The adoption of a crop rotation and the limitation on the application of nitrogen fertilizer to reduce excessive nitrogen is investigated. Limiting nitrogen fertilizer use on cropland susceptible to a high potential for leaching will have a smaller compliance cost than on cropland with a moderate potential for leaching.

"An Economic Model of Pesticide Quality and Quantity Effects on Apple Production." Sandra Archibald (Stanford University) and Tim Brown (University of California, Berkeley)
An economic choice model demonstrates how quality- and quantity-damage control inputs are jointly determined in production-marketing decisions. Empirical identification of pesticides' separate quality and quantity effects indicate a larger impact of quantity-damage control inputs on production and a more significant revenue impact of quality-control inputs.

Policy Issues in Production Analysis (Frances Antonovitz, University of Minnesota, presiding)

"Hysteresis and Asset Fixity Under Uncertainty." Shih-Hsun Hsu and Ching-Cheng Chang (Texas A&M University)
The fixed asset theory, when viewed as an investment/disinvestment theory under uncertainty, implies a simple two-parameter control-limit decision rule. The effects of sunk costs, or the divergence of acquisition costs from salvage values, on the degree of investment/disinvestment irreversibility become more pronounced when uncertainty is present.

"The Distribution of Economic Rent Under Mandatory Supply Controls." Bruce A. Babcock (Iowa State University) and William E. Foster (North Carolina State University)
Quota programs with leasable quota rights create two interest groups: Productions of the commodity and owners of the quota rights. Quota owners lose from an input price increase, whereas quota producers may win. Simulations indicate that a 40% wage hike would increase the producer surplus of tobacco farmers by $30 per acre.

"Field Measurement of Diverted Land Quality and Program Slippage." Dana Hoag (North Carolina State University), Bruce Babcock (Iowa State University), and Bill Foster (North Carolina State University)
The diversion of worst yielding land in acreage reduction programs causes land quality slippage (LQS). Aggregate slippage estimates range from 25% to 50%. Using actual data on over 100 farms in North Carolina, LQS was less than 5%. LQS may therefore be less important than other slippage sources.

"Modeling and Measuring Land-Use Decisions in Rural Areas: The Case of Mining and Farming." John B. Crihfield (University of Illinois)
This paper adapts a labor-market model of employment choice to the simple land-use choices typically confronting landowners in rural areas. The optimization condition from this model is applied to a land-use tussle in Illinois pitting corn versus coal and yields quantitative estimates of alternative landuse values.

Inefficiency Analysis (Richard Perrin, North Carolina State University, presiding)

"Cost Efficiency in U.S. Corn Production." Stephen C. Cooke (University of Idaho) and W. Burt Sundquist (University of Minnesota)
Cost efficiency in U.S. corn production increased about 1.4% per year between 1974 and 1983. Illinois and Iowa have a competitive advantage over Indiana and Nebraska. Very large corn enterprises were 10% to 16% and large enterprises 3% to 8% more cost efficient than medium size enterprises.

"Profit Inefficiency of Indian Farms." Arunava Bhattacharyya and Terrence F. Glover (Utah State University)
This paper attempts to measure the level of profit inefficiency of Indian farms using a stochastic profit function. In the process, the degree of misallocation of inputs and output are also estimated. Results indicate that both large and small farms are profit inefficient and misallocate inputs and output.

"The Causes of Economic Inefficiencies of New York Dairy Farms." Arthur C. Thomas and Loren W. Tauer (Cornell University)
Technical and overall cost efficiencies are measured for 125 New York dairy farms. Explanatory models of efficiencies are estimated to determine how farms can increase their efficiencies. Changes in efficiencies are explained by changes in both assets and prices. Efficiency levels are explained by farm and operator characteristics.

"Efficiency and Regional Comparative Advantage." Barun Kanjilal, H. O. Zapata, and A. M. Heagler (Louisiana State University)
An indicator of economic efficiency and comparative advantage is developed from the classical theory of cost functions. Stochastic properties are derived directly from stochastic cost frontier functions. The methodology is illustrated using aggregated data of production, cost, and prices. Implications for monitoring firm performance and policy analysis are provided.

Technological Innovations (James F. Oehmke, Michigan State University, presiding)

"The Effect of Past Decisions on Present Hybrid Maize Adoption in Malawi: A Polya Process Approach." Melinda Smale (University of Maryland), Paul W. Heisey (CIMMYT), and Madhur Gautam (University of Maryland)
Most farmer decision-making models of technology adoption are static, and those implying certain decision processes over time have not been tested statistically. With data from Malawi, a simplified Polya model is used to test one regularity in intertemporal adoption decisions—that past experience with hybrid seed influences present adoption probabilities.

"Estimating Adoption Behavior from Time of Adoption Data: The Case of Computers in California." Bruce McWilliams and David Zilberman (University of California, Berkeley)
Time of adoption of the variable representing technology adoption is preferable to a dichotomous adopt/not-adopt variable because it provides insight into the diffusion process and indicates intensity of adoption. This paper develops a methodology for estimating the time of adoption and applies it to computer adoption in agriculture.

"Induced Innovation and Long-Run Factor Substitution: Implications for Research and Environmental Policy." George B. Frisvold (ERS USDA)
A model of public research prioritization and technical change in U.S. agriculture is estimated. Technical biases are sensitive to factor prices and to the mix of private and public research. A public research strategy of unit farm cost minimization may amplify static resource misallocations resulting from market distortions or externalities.

Econometric Applications in Production (Matthew T. Holt, University of Wisconsin, presiding)

"The Implicit Value of Corn Base Acreage." Joseph A. Herriges, Nancy E. Barickman, and Jason F. Shogren (Iowa State University)
This paper estimates the implicit value of corn base acreage for twelve Iowa counties by assuming that the benefits of access to the commodity program are capitalized into farmland rents. Using a hedonic pricing approach, the rent gradient for base acreage is found to be $11 to $14 per acre.

"The Effects of Parcel Characteristics on the Value of Agricultural Land in Washington State." Feng Xu (University of Missouri), Ron C. Mittelhammer and Paul W. Barkley (Washington State University)
This study examines the effects of selected parcel characteristics on agricultural land values. A nonlinear hedonic model is estimated for each of six regions in Washington state. The nonnegative nature of land price was modeled directly via a truncated logistic distribution. The truncation effect was significant in half of the regions.

"Heteroskedasticity in Crop Yield Models." Seung-Ryong Yang, Won W. Koo, and William W. Wilson (North Dakota State University)
This study examines three alternative models of heteroskedasticity in crop yield models. Non-nested test results suggest that modeling the sources of heteroskedasticity is the preferred procedure. The results also suggest that the GARCH specification is a promising model of heteroskedasticity when the sources cannot be identified.

"Unit Roots in Multiproduct Acreage Response Systems." J. Stephen Clark and John Spriggs (University of Saskatchewan)
This paper explores the theoretical and empirical issues in unit root nonstationarity for multiproduct acreage response systems. A wheat/barley acreage response system for the Prairie Province region of Canada is estimated and the existence of a unit root is not rejected.

Topics in Risk (Bruce Sherrick, University of Illinois, presiding)

"Aversion to Income Risk in the Presence of Multivariate Risk." James A. Chalfant (University of California, Berkeley) and Israel Finkelshtain (Hebrew University)
We define a risk premium capturing aversion to income risk in the presence of other random attributes in the utility function. Unlike univariate or other multivariate measures, the new measure permits the analysis of decisions that involve a subset of all risks faced by an individual.

"Risk Attitudes About Income Under Discrete Status Levels." David E. Buschena and David Zilberman (University of California, Berkeley)
This paper models farmer behavior when utility depends both on income and on discrete factors of well-being. This "status-model" reveals the potential for model misspecification of preferences and leads to expected utility representations that call for risk-taking behavior for some income levels and risk aversion for others.

"The Export Credit Guarantee Program as a Risk Business." David W. Skully (ERS USDA)
The Export Credit Guarantee facility of the CCC is modeled as a risk business. Because of diffuse property rights CCC's risk management differs predictably from a proprietary risk business. The model is employed to evaluate the performance and cost of credit guarantees and determine whether they are an export subsidy.

"Market-Level Measures of the Value of Weather Information: Conceptual and Empirical Considerations." Frances Antonovitz (Iowa State University)
Assuming risk-neutral producers with rational expectations, *ex-ante* market-level measures of the value of weather information to both consumers and producers are derived and then illustrated graphically using traditional surplus measures. Methods to obtain empirical estimates of these *ex-ante* measures from observed data are derived and discussed.

Empirical Analyses with Risk or Uncertainty (Barry Goodwin, Kansas State University, presiding)

"Risk Forms and Measures in Acreage Response Functions: The Case of Rainfed Mechanized Farming of Sudan." Abdelmoneim H. Elnagheeb (University of Georgia) and Daniel W. Bromley (University of Wisconsin)
An acreage response model for rainfed mechanized farming of Sudan was estimated. Results indicated that an asymmetric risk analysis (ARA) was preferred to a symmetric risk analysis (SRA). Simple measures of risk were preferred to complex measures in the case of SRA but not in the case of ARA.

"Application of a Discrete Stochastic Programming Model to Marketing Decisions Under Price Uncertainty." Joseph S. Neibergs and Bruce McCarl (Texas A&M University)
A discrete stochastic programming model is formulated to maximize expected income. The model analyzes marketing alternatives over three equally likely price probability states in four time periods. The model determines the value of a sequential model that incorporates additional information as time unfolds in comparison to a traditional optimization model.

"Techniques for Measuring Catastrophic Yield Risk." Clemen M. Gonzales, Hai Ping Luo, Jerry R. Skees, and Mary A. Marchant (University of Kentucky)
This paper presents a methodology for adding longer series of weather data to short series on yield data. The objective centered around understanding catastrophic yield risk probabilities implied in historical weather data. Findings demonstrate that the recent 33 years of weather provide yield forecast with significantly less risk than the past 95 years.

"Economic Tests of Firm Decision Making Under Uncertainty: Optimal Output and Hedging Decisions." Timothy A. Park (University of Nebraska) and Frances Antonovitz (Iowa State University)
The competitive firm under price uncertainty which hedges and faces basis risk is examined. Assuming constant absolute risk aversion, reciprocity conditions liking optimal output, hedging, and input decisions and leading to testable econometric restrictions are derived. The theoretical model is empirically tested with data from a large California feedlot.

Dynamic Econometric Models (John McClelland, USDA, presiding)

"A Dynamic Model of the U.S. Beef-Breeding Herd Inventory." Kenneth A. Foster (Purdue University) and Oscar R. Burt (University of California, Davis)
Distributed lag models estimated for cattle inventories suggest an incorporation of biological constraints and the age distribution of the herd which is crucial to understanding the culling/retention decision. The estimated equations are validated using post-sample observations which were withheld prior to estimation, and a potential source of cycles is discovered.

"Expectations and the Dairy Product Promotion Policy." Albert J. Reed (ERS USDA)
Herd dynamics imply that milk supply depends on price expectations. It follows that farmers' computed return on generic advertising depends on the assumption of expectations made in a model. That a rational supply response to a demand shift differs from a naive response indicates consideration be given to this assumption.

"Estimation of Dynamic Nonlinear Rational Expectations Models of Commodity Markets with Private and Government Stockholding." Mario J. Miranda (Ohio State University) and Joseph W. Glauber (President's Council of Economic Advisors)
Stochastic-dynamic programming and disequilibrium maximum likelihood methods are combined to estimate a dynamic nonlinear rational expectations model of the U.S. soybean market. The structural model captures the essential processes governing market dynamics including: private speculative stockholding, government price support intervention, and expectation formation and risk response in supply and stockholding decisions.

"Risk and Rational Expectations in the Broiler Industry: A Multivariate ARCH-M Approach." Satheesh V. Aradhyula (Iowa State University), and Matthew T. Holt (University of Wisconsin)
This paper extends recent work on modeling rational expectations and risk to include time-varying covariances. The estimation framework used is a type of multivariate ARCH-M model. The results show, among other things, that conditional covariances are not constant and are thus important factors in the rational expectations process.

Topics in Econometric Methods (Jeffrey Dorfman, University of Georgia, presiding)

"The Relevance of the Extent of Farm Work to the Analysis of Off-Farm Labor Supply of Farmers." Ayal Kimhi (University of Maryland)
A unique data set, which includes information on farm work of farm operators, is used to demonstrate the importance of using such information in the analysis of off-farm labor supply. Implicit assumptions, which are alternatively used in existing studies, are challenged by the findings and found to be too strong.

"Model Selection with Temporal and Spatial Aggregation: Alternative Marketing Margin Models." Charles C. Lyon (University of Minnesota) and Gary D. Thompson (University of Arizona)
The link between data aggregation and model performance is investigated. Three separate specifications for marketing margins are estimated at six levels of spatial and temporal aggregation. Nonnested hypothesis tests are performed to determine model preference at each level of aggregation. Results demonstrate that model performance is sensitive to data aggregation.

"Modeling Yield with Stochastic Trend and Nonnormal Errors." Charles B. Moss and J. S. Shonkwiler (University of Florida)
Recent interest in modeling randomness in crop yields has typically focused on two distinct areas: stochastic trend and nonnormality. However, the estimated errors from the stochastic trend model fail a test for normality. Thus, a transformation is used to model the nonnormality of errors with the stochastic trend model.

"Granger Test Performance Under Cointegration." Hector O. Zapata, Tae-Hwy Lee (Louisiana State University), and Philip Garcia (University of Illinois)
A Monte Carlo investigation is used to examine the performance of "Granger causality" tests for cointegrated time series. Dynamic specifications allowing for error correction terms are introduced. The results indicate that under normality the tests perform well for large samples but are somewhat sensitive to sample size and equilibrium behavior.

Topics in Quantitative Methods (Ken Foster, Purdue University, presiding)

"Separability Flexible Forms." Paul Driscoll, A. M. McGuirk, and Jeffrey Alwang (Virginia Tech)
Quadratic flexible forms, such as the translog and generalized Leontief, are separability inflexible. That is, separability restrictions render them inflexible with regard to separable structures. A class of functional forms is proposed which is flexible regarding general production structures and remains flexible regarding separable structures when separability restrictions are imposed.

"Aggregation in Mathematical Programming Sector Models and Model Stability." Haryi Önal (University of Illinois) and Bruce A. McCarl (Texas A&M University)
This paper discusses the accuracy and stability of an aggregation procedure based on extreme point generation. Numerical results obtained from an empirical model show that the aggregation procedure is highly satisfactory in terms of aggregation errors and the aggregate model is very stable under objective function parameter changes.

"General Stochastic Dominance Method for Evaluating Management Strategies, with an Application to Mastitis Control in Dairy Cows." Gay Y. Miller, Joseph M. Rosenblatt, Marvin T. Batte (Ohio State University)
The concept of restricted first-order stochastic dominance is developed; it is essentially an analysis which calculates the point at which the cumulative distributions of two different profit functions cross and restricts the underlying utility function accordingly. This is applied to evaluate teat dips used in mastitis control.

"GSD Estimation of the Relative Worth of Cover Crops in Cotton Production Systems." G. Grant Giesler and Kenneth W. Paxton (Louisiana State University), and E. P. Millhollon (Red River Research Station)
Cover crops can help reduce the negative environmental impacts of cotton production. This study used generalized stochastic dominance to evaluate the relative worth, via risk premiums, of four cover crop regimes and two conventional production practices. Results indicate that cover crop regimes may be feasible alternatives to conventional practices.

Consumer Demand for Food and Nonfood Products (Chung L. Huang, University of Georgia, presiding)

"Food Spending in Female-Headed Households." Elizabeth Frazao (ERS USDA)
Female-headed households constitute a large proportion of the food assistance population yet have lower food expenditures than other households. After controlling for income and other socioeconomic characteristics, household type remains an important determinant of food expenditures. The question remains whether lower food expenditures translate into lower food consumption.

"Effects of Income Sources on Household Food Expenditures." Steven T. Yen (Nicholls State University), Wen S. Chern (Ohio State University), and Hwang-Jaw Lee (Tunghai University, Taiwan)
A purchase infrequency model and a Tobit model are used to examine impacts of different income sources

on food expenditures using BLS's Consumer Expenditure Dairy Survey data. Results show that four income components have significantly different effects on the expenditures of food, food at home, and food away from home.

"U.K. Consumers' Willingness to Pay for Leaner Pork Products." Michael K. Wohlgenant (North Carolina State University) and Catherine M. Lemieux (Kansas State University)
U.K. consumers' willingness to pay for leaner pork was estimated using data from 202 in-home interviews in 1989. Econometric estimates were obtained for four products using Heckman's two-step estimator. Mean willingness to pay estimates range from 8.55% for sausage to 12.8% for joints.

"Cross-Sectional Estimation of Market Demand Elasticities for Natural Christmas Trees." George C. Davis (University of Tennessee) and Michael K. Wohlgenant (North Carolina State University)
This paper uses the multinominal nested logit framework developed by McFadden in 1978 to estimate the individual's demand parameters for natural Christmas trees. These parameters are then aggregated to obtain market demand elasticities, which to date have not been estimated.

Food Safety and Health Concern: Results from Consumer Surveys (Helen H. Jensen, Iowa State University, presiding)

"Appropriate Channels for Communication of the Pesticide Residue Risk: An Ordered Logit Model." Patrick J. Byrne, Conrado M. Gempesaw, and Ulrich C. Toensmeyer (University of Delaware)
The paper assesses the marginal probability effects of demographic variables on consumer concerns with pesticide residues and the likelihood of consumer beliefs given different channels of information on produce safety and risks. The ordered logit procedure using maximum likelihood estimator (MLE) was used as the methodology.

"An Ordered Logit Analysis of Public Perception of Chemicals Used in Animal-Food Products." C. K. Halbrendt, C. M. Gempesaw, and J. R. Bacon (University of Delaware)
The logit analysis of this study found that the concern for the use of feed additives, antibiotics, and the perceived risks to human health due to the use of these chemicals reduces meat consumption. The attitudes for concern generally came from female, health-conscious individuals, and those between age 34–54.

"Factors Influencing Purchasing Patterns for Beef and Other Meats." Dale J. Menkhaus, Pierre M. L. Pelzer, Glen D. Whipple, and Ray A. Field (University of Wyoming)
The purpose of this research was to identify factors responsible for changes in individual purchasing patterns for beef and other meats using consumer survey data. Results suggest that health-related factors significantly contributed to reported decreases in beef purchases and increases in purchases of poultry and fish products.

"Incorporating Food Attributes in the Demand for Food: A Cross-Section Study of Oyster Consumption." Chung-Tung Jordin Lin and J. Walter Milon (University of Florida)
This study examines the relationship between consumer's product attribute perceptions, especially food safety perceptions, and long-term consumption of oysters. Statistical analysis of consumer survey data shows that attribute perceptions are significantly associated with both market participation and level of consumption decisions. Yet, safety perception had a negligible behavioral impact.

The Almost Ideal Demand System: Theory and Applications (James A. Chalfant, University of California, Berkeley, presiding)

"Measuring the Impact of Nutritional Awareness on the Demand for Meat Products." John Schmitz (Texas A&M University)
This paper extends recent studies of the impact of nutritional information on food demand. A distributed lag of the Brown and Shrader index as well as a broader measure of nutritional information is used within an AIDS model for meats. Both measures show a significant impact on meat demand.

"Tests for Weak Separability: The Case of Disaggregated Meat Products." Rodolfo M. Nayga, Jr., Oral Capps, Jr. (Texas A&M University)
Tests for weak separability are conducted for disaggregated meat products. These tests for weak separability show that consumers choose among disaggregated meat products of a particular animal origin, and not across animal origins. Scanner data and the linear approximation of the almost ideal demand system model are used in the analysis.

"Correcting the Almost Ideal Demand System for Shifts in the Distribution of Income with Application to the Modeling of Meat Demand." Richard D. Green (University of California, Davis) and William F. Hahn (ERS USDA)
In this paper, we propose an empirical method of correcting for income distribution shifts and apply this method to the modeling of the consumer demands for beef, pork, chicken, and turkey. Our correction method adds considerable explanatory power to the empirical model.

"The Inverse Almost Ideal Demand System." James S. Eales (University of Alberta) and Laurian J. Unnevehr (University of Illinois)
A new demand system is developed and applied to U.S. meat demand. It is dual to the AIDS model of Deaton and Muellbauer and, thus, is called the Inverse AIDS. IAIDS retains all of the desirable theoretical properties attributed to the AIDS model with the exception of aggregation.

Modeling Demand for Meats in U.S. and Other Countries (Wen S. Chern, Ohio State University, presiding)

"Dynamic Taste Change in Meat Demand: An Application of DYMIMIC Model." Xiaoming Gao and J. S. Shonkwiler (University of Florida)
Taste is a latent unobservable variable in utility and demand functions. A dynamic structural latent variable U.S. meat demand model is estimated by the Kalman Filter and a Dynamic Multiple Indicator, Multiple Cause (DYMIMIC) model. Results show that taste changes have been a significant factor affecting beef and poultry demand.

"Asymmetric Demand Responses: A Demand System Approach." Mark G. Brown and Jonq-Ying Lee (University of Florida)
Asymmetry is introduced into the Rotterdam model by allowing the income response to depend on whether real income increases or decreases. The price responses, in turn, are asymmetric through the general and specific substitution terms. Analysis of data on food and three other broadly defined goods suggests presence of asymmetry.

"Demand for Meat Products in the Pacific Rim Region." Oral Capps, Jr., Raymond Kirby, Reyfong Tsai, and Gary W. Williams (Texas A&M University)
The Rotterdam and LA/AIDS models are used to obtain estimates of demand parameters for meat products in Taiwan, South Korea, and Japan. With relatively few exceptions, the elasticities are similar across model specifications. However, demand elasticities are notably different among the various Pacific Rim countries.

"Mixed Demand System: The Canadian Market for Meats." Anuradha Vissa and Giancarlo Moschini (Iowa State University)
A Rotterdam-type differential demand system is developed to study the case of mixed demands where, at the aggregate level, quantities (demanded) of some commodities and the prices of the others are optimally determined to clear the market. The empirical context is provided by the Canadian market for meats.

Parametric and Nonparametric Methods for Demand Analysis (Jonq Y. Lee, University of Florida, presiding)

"Testing the Translog and Almost Ideal Specifications in Demand Systems." Julian M. Alston (University of California, Davis), James A. Chalfant and Ahmad Ramezani (University of California, Berkeley)
Using Lewbel's framework, a demand system that nests both the almost ideal demand system and the translog demand system is estimated for United States meat consumption. Each special case is rejected. The implications of alternative specifications are then explored.

"Detecting the Income-Calorie Link in the U.S.: An Application of Nonparametric Methods in the 1987–88 NFCS Data." Ahmad Ramezani (University of California, Berkeley)
This paper investigates the interaction between income and calorie intake in the United States using the recently released Nationwide Food Consumption Survey data (1987–88). We use regression analysis as well the two nonparametric methods (ACE and LWR) to determine this relationship. We also consider fat intake.

"Testing for Taste Change: A Compromise between the Parametric and Nonparametric Methods." Yong Sakong and Dermot J. Hayes (Iowa State University)
The paper develops and implements a method for detecting structural change in the degree of substitution among goods that uses both parametric and nonparametric techniques.

Potpourri of Demand Analysis (David Eastwood, University of Tennessee, presiding)

"The Economic Impacts of a Ban on Subtherapeutic Antibiotics in Swine Production." Mark Wade and Andrew P. Barkley (Kansas State University)
Supply and demand elasticities for pork are estimated, then utilized to calculate consumer and producer surpluses for the retail pork market. The impacts of a ban on subtherapeutic antibiotics on both consumers and producers are estimated. Estimates of consumer and producer gains given the antibiotic ban are reported.

"Impacts of Demand Expansion Programs on Producers." Glen D. Whipple and Dale J. Menkhaus (University of Wyoming)
It is theoretically shown that demand expansion programs, if not sustained, will result in producers' losses. This hypothesis was tested using an econometric simulation analysis of the U.S. sheep industry. The re-

sults suggest that producer groups should consider the sustainability of demand expansion programs to prevent net producer losses.

"Dynamic Fertilizer Nutrient Demands for Corn: A Cointegrated and Error-Correcting System." Mark Denbaly and Harry Vroomen (ERS USDA)
Past crop-specific models of fertilizer demand, which are mainly static, indicate price-elastic functions, rendering taxes effective in reducing fertilizer use in agriculture. Developing a dynamic model for corn, this study provides strong statistical evidence that nutrient demands are price inelastic both in the short and the long run.

Livestock Marketing (DeeVon Bailey, Utah State University, presiding)

"The Marketing Timing Value of Outlook Price Forecasts." Scott H. Irwin, Mary E. Gerlow, and Te-Ru Liu (Ohio State University)
This study presents results from a comprehensive evaluation of the market timing value of outlook price forecasts. Results of Merton market timing tests indicate that the outlook programs generally produce valuable hog price forecasts. However, the strength of the market timing value tended to diminish as the forecast horizon increased.

"A Component Pricing System for Pork." Sean Mauney, B. Wade Brorsen, and Jay T. Akridge (Purdue University)
A component pricing system for pork is proposed and evaluated. Results suggest that using a total body electrical conductivity (TOBEC) device with a system of multiple lean and fat component prices provides the most accurate carcass valuation. The impacts of porcine somatotropin and ractopomine on pricing system accuracy are also evaluated.

"Forward Contracts and Risk Mitigation in Fed Cattle Markets." Andrew P. Barkley and Ted C. Schroeder (Kansas State University)
A theoretical model of the motivation of fed cattle producers and packers to engage in forward contracts is developed and analyzed. Comparative static results are derived to gain a better understanding of the market impact of forward contracting in both spot and forward markets.

Market Structure (Jay Akridge, Purdue University, presiding)

"Profit Structure Relationships in U.S. Food Industries." Francis Declerck and Bruce J. Sherrick (University of Illinois)
This study examines the usefulness of concentration indices to predict levels in price-cost margins in U.S. food industries. Cross-sectional and pooled regression models indicate that concentration at top 4-firm level, advertising, and advertising squared are the most significant variables in explaining profit. Technology variables are not significant.

"Imperfect Competition in Multiproduct Food Industries with Application to Pear Processing." Joyce Jong-Wen Wann (National Chuing-Hsing University, Taiwan) and Richard J. Sexton (University of California, Davis)
A general conceptual and empirical framework to measure imperfect competition in food-processing industries is presented. The framework permits measurement of imperfect competition in both raw product market and multiple processed product markets. Application to pear processing suggests the presence of market power for raw pears and processed pear products.

"China's Objectives and Its Market Power in World Rice and Wheat Trade." Jianmin Liu and Jeffrey M. Perloff (University of California, Berkeley)
A generalized maximization model of China's grain trade policy is introduced. China's objectives and its market power in world rice and wheat trade are tested. The hypotheses that China is a pure profit maximizer and that China behaves as a price taker in the international rice and wheat market are rejected.

"Measurement and Analysis of Changes in the Size Distribution of Farm Firms." John L. Rodgers (University of North Carolina)
This paper is concerned with analyzing farm size heterogeneity. Several measures of farm size heterogeneity are proposed (gini coefficient, coefficient of variation, and a modified Herfindahl index) and applied to three different measures of farm size. Regression analyses are employed to identify variables associated with farm size heterogeneity.

Price Analysis (Scott Irwin, Ohio State University, presiding)

"The Influence of Nonprice Competition in the Japanese Soybean Import Market." Joyce Cacho and Eluned Jones (Virginia Tech)
Japanese importers differentiate among oilseeds by nonprice factors of foreign material and oil content. Derived market shares and marginal implicit prices indicate that erosion of U.S. market share might be reversed by reducing foreign material content to 1% in combination with documentation of oil content.

"Hedonic Price Analysis of Cotton in Daily Market Reporting." Don Ethridge, Steve Morse, and Carlos Engles (Texas Tech University)

Procedures for hedonic model determinations of market prices, premiums, and discounts for cotton fiber attributes have been developed for daily market price reporting. Model results compared to current market quotations in the Texas-Oklahoma markets track market prices more accurately and without the consistent bias of quotations.

"USDA *Hogs and Pigs* Reports and Livestock-Futures Price Movements." Phil L. Colling (ARS USDA), Scott H. Irwin, and Carl R. Zulauf (Ohio State University)
The effects of USDA *Hogs and Pigs* reports on livestock futures prices are examined. Prices do not react to expected hog inventories but do react to unexpected inventories, supporting the efficient market hypothesis. Evidence suggests that prices overreact to the unanticipated information and can require several days to incorporate information.

"Market Responses to Error-Ridden Government Crop Forecasts." Nancy DeVore (Louis Dreyfus Corp.) and Peter F. Orazem (Iowa State University)
USDA's corn and soybean production estimates can improve the market's forecast of final production. USDA reports are inefficient and often biased. Market agents, in aggregate, weight the report according to bias and add it to a vector of other information to forecast final production.

Dairy Marketing (Deborah Streeter, Cornell University, presiding)

"Measuring Consumer Valuation of Advertising." Anderson Reynolds (Southwestern Bell)
The study presents methods based on household production theory of measuring consumer welfare changes associated with changes in the level of advertising. Canadian fluid milk advertising was employed to illustrate the method of obtaining, in the market good's space, an approximate measure of such welfare changes.

"Advertising Competition and the Mutual Cancellation Hypothesis: The Case of the Ontario Nonalcoholic Beverage Market." Meenakshi Venkateswaran and Henry Kinnucan (Auburn University)
The mutual cancellation hypothesis of competitive advertising is tested for the Ontario market. Results indicate nonalcoholic beverage advertising has increased the overall size of the market in the long run. In the short run milk advertising effectiveness is reduced by competitive advertising, but the former does not affect the latter.

"Dairy Farmer's Valuation of Market Security Offered by Milk Marketing Cooperatives." Brian A. Roach and Cathy A. Hamlett (Pennsylvania State University)
Dairy farmers often cite market security as a major reason for belonging to a milk-marketing cooperative, but quantifying the benefits of market security has been difficult. This paper presents a method of quantification by developing a willingness-to-pay measure based on differences in expected income distributions.

"An Evaluation of the Cost of Seasonality in the U.S. Dairy Industry." Mark W. Stephenson (University of Wisconsin, River Falls), Andres M. Novakovic and James E. Pratt (Cornell University)
A transshipment model of the U.S. dairy industry is constructed to determine the cost of seasonally disparate supply and demand for dairy products. Price incentive/disincentive plans are related to the magnitude of industry-wide savings that could be realized if uniform patterns of production are achieved.

Imperfect Competition in Cattle Markets (Clem Ward, Oklahoma State University, presiding)

"Meatpacker Conduct and Price Dynamics: An Investigation of Live Cattle Markets." Stephen R. Koontz (Oklahoma State University), Philip Garcia, (University of Illinois), and Michael A. Hudson (Cornell University)
Noncooperative game theory is used to model daily regional meatpacker margins. A specific discontinuous pattern will be observed in margin behavior if market power is exercised. This pattern was tested for and found to persist in four central U.S. markets. The monetary extent of the market power is quantified.

"Buyer Concentration in Feeder Cattle Markets." DeeVon Bailey (Utah State University) and B. Wade Brorsen (Purdue University)
The level of buyer concentration at the nation's two largest cash feeder cattle markets was investigated. Buyer concentration was found to be seasonal. Average concentration ratios increased slightly between 1987 and 1989. This slight increase has depressed prices between $0.13 per hundredweight and $0.46 per hundredweight between 1987 and 1989, depending on the market.

"Market Power in the Beef Packing Industry." Kyle Stiegert (Purdue University) and Azzeddine Azzam (University of Nebraska)
The purpose of this research is to test for noncompetitive behavior in the purchasing of fed cattle by beef packers. The null hypothesis of competitive pricing is rejected. Further analysis is performed to determine if market factors change the degree of market power.

Market Dynamics (B. Wade Brorsen, Purdue University, presiding)

"Systematic and Random Price Variations: Impact of a Centralized Auction System." Zhigang Chen and Rebecca Lent (University of Laval)
Analysis of the composition of price variation indicates a decrease in the random component and an increase in the systematic component since the installation of an electronic auction system for hogs in Québec. Weak-form tests support the hypothesis that the system is more efficient than direct sale by farmers.

"A Dynamic Disequilibrium Model for the Corn Market." J. S. Shonkwiler and G. S. Maddala (University of Florida)
Recent results on the specification and estimation of disequilibrium models are applied to the U.S. corn market. Attention is focused on accounting for dynamics and the formulation of price expectations under price supports. Also, full information estimation is compared to a two-step estimation approach.

"An Evaluation of Farm Retail Price Spreads for Pork in 1990." William F. Hahn and Lawrence A. Duewer (ERS USDA)
Farm-to-retail price spreads for pork set new records in 1990. We evaluated these price movements using a model of asymmetric price transmission. Initial performance was good, but the model's forecasts seriously underpredicted spreads in the last half of 1990, which we consider circumstantial evidence of some change or aberration.

Modeling Issues in Marketing (Joyce Hall, Colorado State University, presiding)

"The Cost Structure of Cooperative and Investor-Oriented Grain and Farm Supply Firms: A Multiproduct Analysis." Jay T. Akridge and Thomas W. Hertel (Purdue University)
A multiproduct cost function was used to compare the efficiency of midwestern cooperative and investor-oriented grain and farm supply firms. Results suggest that cooperatives are no less efficient in a cost sense than their investor-oriented counterparts. However, investor-oriented firms may be more effective in their use of plant and equipment.

"An Analysis of the Current Chinese Crop Sector: An Application of a Duality Approach to a Mixed System of Planning and Markets." Shihua Pan, Satheesh V. Aradhyula, and Stanley R. Johnson (Iowa State University)
Procurement prices, state quotas, and free market prices affect farm decisions in the current Chinese agriculture. This study incorporates procurement prices and quotas into a crop supply model for the Chinese economy and estimates output supply and input demand equations using a dual framework. The estimated model implied plausible elasticities.

"Effects of Decoupling on the U.S. Rice Industry: A Comparison of Simulation and Analytical Methods." Lois Schertz Willett (Cornell University) and Satoko Watanabe (University of Texas)
The model coefficients and validation statistics of a dynamic national rice industry model are presented. Short- and long-run elasticities are compared with other studies. Simulation and analytical methods for testing convergence and evaluating long-run values are examined. Differences with regard to the effects of decoupling policies are analyzed.

"Price Determination in Structural Models: A Comparison of Alternative Inverse Demand Specifications." Dean T. Chen and Gerard Dharmaratne (Texas A&M University)
A theoretical framework is proposed to evaluate price determination behavior of alternative inverse demand specifications of structural models. Price impacts of a wheat model to a supply shock indicated that inverse domestic demand and inverse export demand were inappropriate specifications, while inverse stock demand specification generated credible results.

Issues in Agricultural Water Policy (Steve Crutchfield, ERS RTD USDA, presiding)

"Environmental Degradation and Technological Change." Farhed Shah (University of Connecticut) and David Zilberman (University of California, Berkeley)
A region's underground capacity to store agricultural drainwater is modeled as an exhaustible resource. This resource is typically overexploited by competitive farmers. Tax schemes are proposed to promote the adoption of irrigation technologies that would reduce drainwater generation. Data from California is used to illustrate the results.

"An Analysis of Policy Alternatives for Pivotal Externalities." Marca Weinberg (ERS RTD USDA), Catherine L. Kling, and James E. Wilen (University of California, Davis)
This paper examines policy alternatives for pivotal externalities. A theoretical model of the welfare losses from nonoptimal policies relative to the pareto optimum is examined. The magnitude of these costs are demonstrated with an example drawn from the agricultural drainage problem in California.

"The Search for an Optimal U.S. Agricultural Water Quality Policy." William E. Martin (Illinois State University) and Wesley D. Seitz (University of Illinois)

A generalized total systems model of agricultural production and water quality is outlined. Contributions of economists to components of the system are reviewed. Economic investigation has been fragmented, but weak generalizations can be made. Generalization for policy will require comparisons between many large-scale models rather than any single optimization.

Firm-Level Impacts of Environmental Quality Regulations (John Horowitz, University of Maryland, presiding)

"The Relative Efficiency of Different Standards When Firms Vary." Gloria E. Helfand (University of California, Davis)
This paper uses a simple functional form to examine the effects of different forms of pollution standards on héterogenous firms. A pollution-per-output standard can lead to higher output and higher profits than a pollution standard when firms vary.

"Farm-Level Impacts of Improving Environmental Quality Under Risk." Parveen Setia (ERS CED USDA) and David Letson (ERS RTD USDA)
Nonpoint-source pollution can be reduced by altering land use. A methodology to evaluate alternative management systems and the resulting economic and environmental impacts under risk is presented. Results show that a 20% reduction in leaching losses decreased net income by only \$50 to \$600 depending upon the level of risk aversion.

"Integrating Economic and Environmental Considerations into the Fertilization Decision Process." Nicola Mentonelli, W. G. Boggess, and J. W. Jones (University of Florida)
A van Kuelen fertilizer response model that empirically integrates economic, agronomic, and environmental considerations was applied to an analysis of nitrogen fertilizer of corn in the Coastal Plains. The results suggest that the previous emphasis in the literature on "optimal carryover rates" and "fertilizing the soil" are inconsistent with both economic and environmental goals.

Benefits and Costs of Environmental Improvements (Kenneth E. McConnell, University of Maryland, presiding)

"Food and Environmental Contamination Risks: Does Information Disclosure Reduce Welfare?" Douglas J. Krieger and John P. Hoehn (Michigan State University)
Several recent studies suggest that information about health risk may reduce welfare. This contradicts the conclusions of expected utility theory. This paper explores two sources of this confusion, (*a*) the use of objective risk assessments, and (*b*) failure to properly distinguish between measures of welfare change and information value.

"A Unanimous Consent Solution to the Supply of Public Goods: Getting PPI Rules from a PI Process." Michael C. Farmer (Ohio State University)
This paper presents a cooperative bargaining model for the supply of nonrival goods. Model departs from classic cooperative games by accepting both a second-best framework and core-reducing behavior from the implementation problem. The solution admits the Kaldor-Hicks hypothetical consent efficiency rules as decision rules to a unanimous consent game.

"Valuation of Open Space as a Composite Environmental Good via Conjoint Analysis." John Mackenzie (University of Delaware)
This paper analyzes individuals' preferences for protection of open-space parcels, described by their constituent amenities, within the public choice framework of a statewide open-space preservation initiative. An indirect utility index estimated from these preferences yields marginal valuations of individual amenities within acceptably narrow confidence intervals.

"Estimating Consumer Surplus in the Censored Linear Model." Daniel M. Hellerstein (ERS USDA)
This paper examines the use of the tobit estimator when predicting consumer surplus. It is shown that even when the tobit yields consistent coefficient estimates the OLS does not, inappropriate use of the tobit coefficients may worsen estimates of consumer surplus. A Monte-Carlo simulation illustrates this and other points.

Evaluation of Extension and Teaching Programs (Ernest E. Davis, Texas A&M University, presiding)

"Multiple Objective Evaluation: Business Retention and Expansion Programs." Scott Loveridge (University of Minnesota), Thomas R. Smith (Chicago State University), and George W. Morse (University of Minnesota)
Factor analysis is used to condense evaluations of program success on several objectives into a single index. This index provides means to examine how structure influences overall outcome. Successful programs appear to focus on manufacturing firms, produce written reports, and have coordinators who spend substantially more time on the program.

"Building an Interdisciplinary Team for Sustainable Agriculture Extension Education." Luanne Lohr, Oran Hesterman, James Kells, Douglas Landis, and Dale Mutch (Michigan State University)

An individual component approach is frequently used in evaluating cropping systems. Only a systems approach captures the interaction of components in reduced chemical regimes when comparing across systems. A successful whole-systems-based extension program developed by an interdisciplinary team is described, and suggestions for team building are provided.

"Exam-Taking Ability and Student Performance on Exams." Vern Pierce and Ron Deiter (Iowa State University)
This paper examines the relationship between student exam scores and their exam-taking ability as measured by the order to exam completion. Results of the research presented in this paper should be reassuring to instructors who primarily base student course grades on student test scores.

"Examination Requirements and General Characteristics of Graduate Programs in Agricultural Economics." John C. Foltz and Marshall A. Martin (Purdue University)
A 1989 survey of 30 agricultural economics departments that offer Ph.D. programs indicated a diversity of requirements with 93% and 73% requiring microeconomic and macroeconomic examinations, respectively. The average Ph.D. program required 4.6 years. No statistically significant association was found between departmental rankings and selected program characteristics.

Agriculture and Environment (Farhed Shah, University of Connecticut, presiding)

"Farm Programs and Pesticide Demand." Gerald A. Carlson and Shangnan Shui (North Carolina State University)
It is demonstrated that acreage diversions in the presence of asset fixities and input substitution can decrease pesticide use and dominate price support effects. Significant negative effects are found for policy variables on quantity and quality of demand for corn, soybean, and cotton pesticides utilizing econometric models.

"Farm Programs and Climate Change." Jan K. Lewandrowski and Richard J. Brazee (ERS RTD USDA)
By encouraging or discouraging adaptations to new environmental conditions, farm programs could greatly affect the costs of climate change. On balance, today's programs seem susceptible to climate-change-driven cost increases. Some policy tools and program changes, however, would facilitate adaption and so could help lower the costs.

"Costs and Benefits of Cropland Retirement for Meeting Water Quality Goals." Marc O. Ribaudo and C. Tim Osborn (ERS USDA), and Kazim Konyar (California State University)
One option for addressing agricultural NPS pollution is to retire cropland in problem areas. The USARM model is used to analyze national welfare costs of a retirement program. The results indicate that efficiency is increased if certain types of cropland are retired, rather than all cropland in designated problem areas.

"Regional Implications of National Land Retirement Programs." Michael R. Dicks (Oklahoma State University) and Ian McCormick (ERS USDA)
Nearly one-third of cropland used in the production of the major food and feed grains was idled by land retirement programs in 1987. The geographic distribution of the idled acreage varied by crop and program. The variation in geographic distribution led to considerable variation in the impacts on regional, state, and local economies.

The Government as a Policy Agent (Dawn Thilmany, University of California, Davis, presiding)

"Optimal Policy Instruments and Political Preference Functions." Tilman Becker (University of Kiel, F.R. Germany) and B. Stephan Labson (University of California, Berkeley)
Most U.S. farm policies redistribute income to producers. This paper examines an open economy by connecting the framework of efficient surplus transformation and policy preference functions to demonstrate that efficiency in redistribution is increased if the domestic consumption price is introduced as a new policy instrument.

"The Importance of Political Markets in Formulating Economic Policy Recommendations." Coleman Bazelon (University of California, Berkeley)
The impact of incomplete modeling, both economic and political, are examined. It is shown that neglecting the political market in which policies are adopted can lead to larger errors than ignoring the connections between policies that are interrelated.

"Optimal Lobbying Behavior and Government Response: Implications for Agriculture." Marcel Fafchamps (Stanford University), Elisabeth Sadoulet and Alain de Janvry (University of California, Berkeley)
A general equilibrium model with optimal lobbying behavior and endogenous government behavior is solved numerically. It predicts that sectors which are more flexible, larger, and produce commodities with lower income elasticities and higher budget shares tend

to be disprotected, explaining the price bias against agriculture in developing countries.

"Determinants of Philippine Sugar-Pricing Decisions."Rigoberto A. Lopez (University of Connecticut)
This paper develops and estimates a model of political-economic decision making with respect to consumer prices for sugar in the Philippines. Results underscore the importance of distributional and political factors in determining these prices, particularly the role of various presidential administrations and the U.S. sugar quota.

Trade and Policy (Coleman Bazelon, University of California, Berkeley, presiding)

"The 30-30-30 Proposal: CGE Simulation of Unilateral Compliance by the U.S.A. to Partial Trade Liberalization." Maureen Kilkenny (Pennsylvania State University)
A CGE model of the U.S. is applied to analyze unilateral compliance with the current partial liberalization proposal to the GATT. A key issue is voluntary participation in the programs. The main implications are that economy-wide real GDP could increase by $6 billion, farm income per FTE could rise by 3%, while returns to cropland fall by 15%.

"Measuring the Effects of Real Exchange Rate Policies in Agriculture." Steven C. Kyle (Cornell University)
This paper discusses the importance of (*a*) the determinants of tradability in agricultural markets, (*b*) the irrelevance of results based on "free trade" equilibria to polilcy analyses, and (*c*) the importance of the characteristics of crop production functions in estimating the effects of real exchange rate changes on the agricultural sector.

"The Side Effects of Supply Controls: Export Market Effects of Domestic Peanut Policy." Randal R. Rucker and Walter N. Thurman (North Carolina State University)
The focus of the U.S. peanut program is the domestic market for edible uses, where marketing quotas, price supports, and import restrictions maintain high prices. However, the rules restricting sales onto the domestic edible market also have important, albeit indirect, effects on the export supply of U.S. peanuts.

"The Political Economy of Tariffs on U.S. Food Manufacturing." Emilio Pagoulatos and Rigoberto A. Lopez (University of Connecticut)
This paper estimates a simple model of tariff formation for U.S. food-manufacturing industries based on a political market for protection. Findings indicate that higher tariffs accrue to declining, low-skill, labor-intensive, and concentrated industries which actively lobby by supporting particular congressional candidates in elections.

Analysis of Specific Agricultural Policies (Alain de Janvry, University of California, Berkeley, presiding)

"Farm Labor Contractors, Turnover, and the Impact of IRCA on the Farm Labor Markets." J. Edward Taylor and Dawn Thilmany (University of California, Davis)
Employer sanctions under IRCA are intended to force U.S. employers to adjust to a smaller, more legal work force. This paper focuses on farm labor contractor activity as a vehicle to test IRCA's effectiveness. Findings do not support the hypothesis that IRCA has succeeded in reducing the flow of new immigrants to California agriculture.

"ASCS Program Yields: Policy Implications for Regional Resource Allocation." Barry J. Barnett and Jerry R. Skees (University of Kentucky)
This paper addresses a number of issues with respect to ASCS program yields. In particular, results from simple regression models suggest that ASCS yields reflect yields per harvested acre rather than yields per planted acre. These results have significant policy implications for both regional resource allocation and crop insurance.

"U.S. Food Assistance Programs: Measuring the Benefits to Producers." Steve W. Martinez and Praveen M. Dixit (ERS USDA)
U.S. food assistance programs led to additional food expenditures of $9.4 billion in 1989/90. The additionality per dollar was higher from School Lunch and School Breakfast programs (1.0) than for the Food Stamp Program (.28). Farm income rose by 7¢ for each dollar of food assistance.

"Possible Impacts of 1990 Ethanol Legislation on Agriculture." John N. Ferris (Michigan State University)
Federal ethanol legislation in 1990 may eventually increase net cash farm income but will negatively affect producers of livestock, vegetables oils and soybeans, and the EC's CAP. Corn prices will be as much as 8% to 10% over the baseline and soybean prices as much as 2% to 4% below.

Editorship, Research Money, Inequality, and Government (Anderw Schmitz, University of California, Berkeley, presiding)

"Editorship Location and Distribution of Authors." Kevin J. Hurt (Texas Tech University),

Josef M. Broder (University of Georgia), R. Terry Ervin, and Eduardo Segarra (Texas Tech University)
Relationships between editorship location and regional distribution of authors in the *AJAE* from 1944–89 are examined. Results suggest that editorship location has had short-term effects on the regional distribution of authors. A longer-term analysis suggests that *AJAE* editorship policies have maintained regional accessibility and representation among its contributors.

"An Analysis of Allocation of LISA Research and Extension Funding." Wesley N. Musser and David G. Abler (Pennsylvania State University)
This paper considers a political economic factors associated with allocation of federal LISA funds among states. A simultaneous equation, tobit model is estimated with LISA allocations and pressure group memberships the endogenous variables. Economic, environmental, and political exogenous variables and the endogenous variables are significant in the model.

"Single- and Multi-Dimensional Theil Inequality Measures: An Application to Farm Households." Stephan J. Goetz (University of Kentucky)
Earlier analyses of farm-level inequality are extended by incorporating measures of inequality between groups of farmers and multiple attributes, including years of education. Single- and multi-dimensional inequality declined between 1985 and 1989. A sharp decrease occurred in inequality among gross farm sales between full- and part-time farmers.

"Are Government Transfers Efficient? Problem in Testing the Efficient Redistribution Hypothesis." David S. Bullock (University of Illinois)
Previous testing of the ERH has neglected (*a*) simultaneous use of policy instruments and (*b*) to differentiate between the effects of market elasticities on total versus marginal deadweight costs. Results are (*c*) improper conclusions about the consequences of market changes on transfers and (*d*) inadequate testing of the ERH.

Models of Agriculture with Policy Implications (Emilio Pagoulatos, University of Connecticut, presiding)

"Wheat Buffer Stock Policy Alternatives." Carl Zulauf, Dee-Yu Pai, and Luther Tweeten (Ohio State University)
Grain stocks largely have been unplanned byproducts of commodity price support programs. This paper estimates the economic impact of alternative wheat buffer stock policies. The economic implications of seven stock policy alternatives were examined herein ranging from a free market to solely government storage managed by various rules.

"Dynamics of Structural Change in the Ontario Hog Industry." Mike von Massow, Alfons Weersink, and Calum G. Turvey (University of Guelph)
This paper shows the decline in total number of active hog producers in Ontario will slow and size distributions will stabilize. Changes in the farm size distribution could be moderated with some form of hog price or feed subsidy; however, its effectiveness would be limited to the smallest production units.

"A Multimarket Bounded Prices Model Under Rational Expectations: The Case of Corn and Soybeans." Matthew T. Holt (University of Wisconsin)
This paper extends the bounded prices model under rational expectations to a multimarket setting. The resulting framework is used to estimate a supply-demand model for corn and soybeans. The estimated model is used to simulate the implications of removing price support and diversion programs over the sample period.

"Implications and Existence of Federal/Private Forage Market Interdependence." Alan R. Collins (West Virginia University)
Market interdependence creates nonzero cross elasticities between federal and private forage markets. Given its existence, private forage market prices are inappropriate for determining a fair market value for federal forage under both first- and second-best pricing assumptions. A case study is used to estimate empirically the existence of market interdependence.

Posters

"Transaction Costs, Vertical Coordination, and the Competitive Performance of the U.S. Food Industries." Stuart D. Frank (USDA) and Dennis R. Henderson (Ohio State University)
The structure and competitiveness of the U.S. food industries is influenced by transactional inefficiencies and the coordination arrangements used in vertical organization. The empirical results show that transaction costs are a primary motivation for vertical coordination. The research results also indicate vertical coordination significantly affects food industry performance.

"Price Differentials for Organic Produce." Neilson C. Conklin, Gary D. Thompson, and Lyle D. Riggs (University of Arizona)
This study uses hedonic price analysis to investigate retail price differentials for organic and conventional produce items. Price differentials are a function of produce quality, labeling, store, and seasonality. Produce quality, type of retail outlet, and seasonality all play important roles in explaining differences in organic produce prices.

"Alternative Crop Production and Marketing Strategies in the Lower Mississippi Delta Region." Magid Dagher and Gayle Pounds (University of Arkansas)
This study identified, described, and evaluated those alternative cropping patterns and marketing strategies that could improve the profitability of farming operations, minimize fluctuations of farm income, and enhance the quality of life of farms and rural communities in the Lower Mississippi Delta Region.

"Measuring Attitudes Toward Food Safety." Sukant K. Misra and Chung L. Huang (University of Georgia)
The study measures and models consumer attitudes toward pesticide residues on fresh produce by using the Likert attitude scaling and ordered probit procedures. The results suggest that both demographic and psychographic (product attribute preferences, nutritional concerns, and knowledge) characteristics are significant determinants of consumers' risk perception about pesticide residues.

"Aquaism: A Dynamic Simulation Model for Vertically Integrated Aquaculture Enterprises." C. M. Gempesaw, II, J. R. Bacon (University of Delaware), D. Lipton (University of Maryland) and J. Richardson (Texas A&M University)
Financial simulation has been used in past studies to evaluate the impact of new tax laws, public policies, and investment expansion decisions. This paper presents an important extension of financial simulation to vertically integrated, multiple output, multiple input aquaculture enterprises using dynamic, stochastic capital-budgeting techniques.

"U.S. Demand for Edible Peanuts: The Impact on Farmers' Income." Dale H. Carley and Stanley M. Fletcher (University of Georgia)
The inelastic demand for peanut products results in demand increasing considerably less than prices decreasing. Demand relationships were then used to project the use of edible peanuts under two policy scenarios. Farmer income under the GATT scenario would be $326 million less than under the continuation of the current program.

"Cotton Production and Water Quality: An Initial Assessment." Stephen R. Crutchfield, Marc O. Ribaudo, Parveen P. Setia, David Letson, and LeRoy Hansen (ERS USDA)
Data from a survey of cotton farmers is used with environmental assessment models to measure potential water quality effects of cotton production. High potential for pesticide leaching is found to be less widespread than potential leaching of nitrates or losses of pesticides to surface water from cotton acreage.

"Using Rent to Value Ratios to Gauge Nonfarm Demand for Farmland." Karl Gertel and Felix Llacuna (ERS USDA)
Nonfarm demand for farmland is associated primarily with expansion of urban areas. Farmland rent-to-value ratios were used to gauge the extent and distribution of nonfarm demand. It was found that nonfarm demand for farmland is more widespread than urban expansion and most often found on grazing land.

Not-for-Profit Land Trusts and Farmland Protection Programs: Results from a Survey in the Northeastern U.S." Nelson L. Bills and Stephen Weir (Cornell University)
Increasing numbers of private land trusts are implementing farmland protection programs. This paper reports on a survey of more than 500 land trusts in the Northeastern U.S. About one-third currently protect agricultural land. Protection techniques are diverse, but much attention is focused on acquiring farmland through donations from private landowners.

"Policy Implications of Farm Family Labor Allocation in Virginia." Judith I. Stallman and Jeffrey Alwang (Virginia Polytechnic Institute and State University)

Over half of Virginia's farms are defined as part-time because they do not employ the operator full time. Off-farm work constraints cause part-time farm families to allocate their resources differently than full-time farm families. As a result, part-time and full-time farm families will respond differently to policy measures.

"Volunteer Visitor Business Retention and Expansion Programs: Overview and Outcomes." Scott Loveridge and George W. Morse (University of Minnesota)
Twenty-six states now sponsor business retention and expansion programs. Extension is supporting seventeen state programs. Objectives include helping small communities develop strategic economic development plans and solve local business problems. Evaluation surveys show that local coordinator time allocation and methods of volunteer training influence attainment of objectives.

"Education and Poverty in Rural Kentucky." Stephan J. Goetz and David L. Debertin (University of Kentucky)
Costing over $1 billion, the educational reform package recently implemented in Kentucky was intended to equalize per pupil spending across school districts. The poster analyzes some of the impacts of the reform and demonstrates that low-income agriculture- and mining-dependent counties received the largest increases in per pupil spending.

"Ranking Investments with B/C and IRR." Angelos Pagoulatos and David L. Debertin (University of Kentucky)
This display illustrates some of the new computer software we have developed for using the B/C ratio and the IRR for ranking alternative investment projects. The example chosen is the calculation of the B/C ratio using a time period of three years. Net incremental benefits are derived and the IRR is calculated and interpreted. A series of computer-generated slide shows dealing with analysis of investments has been developed.

"A Farm Sector Paradox: Can Real Factor Income Increase While the Sector Sheds Factors?" Gerald Schluter (ERS USDA)
A graphical presentation of evidence illustrates the paradox of declining factor commitment to and rising real factor income from the U.S. farm sector anchors this poster proposal. Supporting materials motivate the relevance to the profession of exploring the paradox and explore policy, statistical, and structural implications of the paradox.

"Limited Resource Farms: Characteristics and Needs." J. Perry, M. Ahearn, and E. Nielsen (ERS USDA)
Using data from the 1988 Farm Costs and Returns Survey, characteristics of small farms with low asset value and low incomes are presented. Geographic location, average acres operated and debt/asset ratios, operator age and educational level, percentage engaged in full-time farming, household income, and percentage in poverty are shown.

"Interdependence of U.S. and EC Dairy Policies." Steven A. Neff (ERS USDA) and Mary A. Marchant (University of Kentucky)
EC dairy policy changes in the 1980s were largely responsible for international market disturbances that were felt in the U.S. market in 1989. A more flexible and more outward-looking U.S. dairy price support program could have acted to reduce the instability experienced in the U.S. market.

"Evaluation of the Wheat Export Enhancement Program 1991–95." Stephen L. Haley (Louisiana State University)
Research results indicate that the EEP will have a significant effect on U.S. wheat exports 1991–95, but will be subject to rapidly diminishing returns at high funding levels. The European Community can effectively counter the EEP at low cost. Other wheat exporters will bear the brunt of EEP in the world wheat market.

"Potential Impacts of Tax Harmonization upon Cigarette Consumption in the EC." Kim Jensen (University of Tennessee), Terri Raney (ERS USDA) and Dan McLemore (University of Tennessee)
Under EC harmonization, a minimum tax rate on cigarettes sold in EC countries has been proposed. This poster projects impacts of harmonization. Setting a minimum rate would decrease per capita consumption and increase per capita tax revenues. Setting a single target rate would increase dispersion of per capita consumption.

"Demand for the U.S. Softwood Logs: An Econometric Study." Farhad Niami (Louisiana State University) and Lalehrokh Homayounfarrokh (Oregon State University)
An econometric analysis of trade concerning Japanese import of softwood log from the U.S. has been conducted. Two import demands consisting of one linear and one log-linear relationship have been developed. The results indicate that demand relationships in both cases are inelastic.

"Overview of the Static World Policy Simulation (SWOPSIM) Modeling Framework." Vern Roningen and John Sullivan (ERS USDA)
This poster helps potential users understand the basic features of the Static World Policy Simulation

(SWOPSIM) modeling framework and evaluate its suitability for their problems. The overview concludes with an illustrated example using the SWOPSIM framework to construct and utilize a demonstration model.

"EC 1992 and Its Banana Split." Liana C. Cuffman Neff and Terri Raney (ERS USDA)
The European Community (EC) plans to eliminate internal trade barriers by the end of 1992. EC members employ three different trade regimes for banana imports which depend on the existence of internal barriers. We examine the theoretical and empirical implications of the EC banana market and analyze different policy scenarios for reform.

"On-farm and Public Policy Evaluation of Sustainable Agriculture." Thomas L. Dobbs (South Dakota State University)
South Dakota State University is nearing completion of a 3-year, foundation-funded study of sustainable agriculture and the effects of alternative public policies on sustainable agriculture. Surveys and on-farm investigations have generated data for economic comparisons of conventional and sustainable farms in five different agroclimatic areas of South Dakota.

"Modeling Soil Erosion Control Policy." Robert R. Alexander and Burton C. English (University of Tennessee)
A multilevel dynamic model is developed, which optimizes the producer and policy maker dynamic problem, explicitly recognizing the actor interrelationships. The second stage weights the relative importance of the policy maker's competing goals, resulting in a dynamic policy frontier demonstrating the relationships between policy goals and the resulting optimal solution paths.

"Measuring the Effect of Adopting an Improved Management Practice on Expected Returns and Risk of Fresh Market Vegetables." J. Walter Prevatt (Auburn University)
A Target MOTAD model was formulated to examine the return-risk relationships associated with debt level and irrigation method of multiple-cropped fresh market vegetables. The impact of debt level and irrigation method on enterprise mix, expected returns, and risk magnitudes was substantially different for the six risk-efficient frontiers.

"Biofuels from Energy Crops: Economics Energy Balance and CO_2 Emissions." Mahadev Bhat, Burton English (University of Tennessee), and Anthony Turhollow, Jr. (Oak Ridge National Lab)
Research in the last decade showed that biofuels from energy crops could be at least in part a potential alternative for conventional fossil fuels. From an environmental perspective, production of biofuels is proven to be relatively benign. Present technology needs to be improved to make biofuels competitive with gasoline. Present study attempts to identify nation's region and potential biomass species having comparative advantage in terms of cost of production, CO_2 emission and energy consumption. This poster highlights the relative cost structure from biomass production, transportation through biofuel conversion. The poster should provide insight regarding the economics of biomass crop production to policy makers, students, and researchers.

"Farm Management of Leased Land—Does Landlord Gender Matter?" Denise M. Rogers and Ann M. Vandeman (ERS USDA)
Data from the 1988 follow-up survey to the Census of Agriculture are used to estimate a model of landlord participation in farm management decisions. Landlord involvement is estimated as a function of gender and other landlord characteristics, characteristics of the operator, tenure arrangements, and type of organization.

"Effects of Variety Rotation and the Feed Grain Program on Soybean Pest Management." G. V. Chomo and G. A. Carlson
Near-optimal crop rotations for soybean nematode control depend upon relative yield of resistant to susceptible soybean varieties and corn target prices. High target prices increase corn planting rotation percentage from 50% to 70% and eliminate use of resistant soybean varieties. These results come from a flexible model for nematode management.

"Risk Assessment of 1991 Farm Program Alternatives for Corn Using '@RISK(c)' a 'Lotus-1-2-3(c)' Add-In." James L. Novak, Robert G. Nelson, and Robert Goodman (Auburn University)
Corn budgets were developed for planting alternatives available under the new farm bill (1991–95). A 'Lotus 123(c)' Add-In called '@RISK(c)' was used to assess risk-return trade-offs for these alternatives. The effects of using futures options and/or Multiple Peril Crop Insurance to further reduce risk were explored.

"Development of an Operational Farm-Level Marketing Plan Template: A Systems Approach." Ward E. Nefstead
This poster examines the farmer decision process in making a farm-level marketing decision and provides working templates to utilize in organizing the relevant information. Decisions dealing with "what, how, when, and where to market" are addressed in different parts of the templates. This utilizes a systems approach including accounting data to measure the extent of current marketing efforts and a cumulative position on products sold.

"Diversity in U.S. Agriculture: A New Delineation by Farming Characteristics." Judith E. Sommer and Fred K. Hines (ERS USDA)
Patterns of agricultural production across the nation are revealed in a new delineation that groups counties by 27 characteristics related to agriculture. We use cluster analysis to combine 2,972 counties into 12 clusters that are relatively homogeneous with respect to three dimensions: farm enterprise, farm resources, and farm-nonfarm linkages. This delineation is useful in assessing regional differences in farm sector response to public policy changes.

"An Economic Comparison of Alternative Irrigation Systems." S. H. Amosson (Texas A&M University)
The net investment and discounted savings of five irrigation systems are compared to a typical furrow irrigation system. Scenarios with intermediate and high water requirements yielded positive returns by converting to more efficient irrigation systems. The effect of major factors affecting irrigation adoption are provided through a sensitivity analysis.

"Computer Cartography and the Display of Rural Economic Information." David L. Debertin and Stephan J. Goetz (University of Kentucky)
Contemporary computer graphics provides an excellent means for displaying rural economic data using maps of geographic regions. This display illustrates some recently developed applications of computer cartography to geographically illustrate economic data as applied to rural counties for the entire U.S. within individual geographic regions and within individual states.

"Financial Dimensions of Farm Production Decisions: An Alternative Teaching Approach." Lonnie R. Vandeveer, Kenneth W. Paxton, and David R. Lavergne (Louisiana State University)
Procedures are presented for introducing risk and explaining farm portfolio choice in undergraduate classes. Modeling procedures allow development of numerical examples which illustrate farm enterprise and capital selection. Procedures are easily adapted to microcomputer spreadsheet analyses and provide a means for improving the student's understanding of financial management concepts.

"An Assessment of the AAEA Meetings." Josef M. Broder (University of Georgia) and Paul W. Barkley (Washington State University)
Findings of a Professional Activities Committee survey of the 1990 Vancouver AAEA meetings are presented. Participation rates, assessments of sessions, and willingness-to-pay by conference registrants are summarized. Recommendations for changes in sessions, nonsession activities, and conference formats are presented. Issues, problems, and opportunities for improving the AAEA meetings are discussed.

"Computerizing a Wholesale Produce Auction to Improve Efficiency and Provide Marketing and Farm Management Information." James C. Hanson and N. Girirajam (University of Maryland)
In 1989, a wholesale produce auction was established in southern Maryland. Over 200 grades and types of commodities were traded in 1990. A computer program was developed to improve auction efficiency. This program has also proved invaluable in providing accurate prices and production information for marketing and farm management programs.

"Extension of Crop Insurance Evaluation System to Growers." Ashley C. Lovell, Gregory Allen, James W. Richardson, and Peter Zimmel (Texas A&M University)
CIRMAN (Crop Insurance Risk Management Analyzer) is an expert system software program designed to evaluate crop insurance alternatives and make recommendations. The objective of this project is to evaluate alternative educational delivery methods for maximizing the benefits of CIRMAN as a decision aid in making crop insurance purchase decisions.

"Simulating and Accounting for Futures Trading in a Teaching Environment." Roger A. Dahlgran (University of Arizona)
A computer program that accounts for student's futures trading activity will be presented. The audience will be able to interact with the software as if they were a student or the program administrator. Evaluative data on the implementation of the program will also be made available.

"Optimal Replacement Decisions for Range Cows." Russell Tronstad and Russell Gum (University of Arizona)
A decision tree of dynamically optimal biannual replacement strategies was solved that considers the cow's age, calf-replacement-slaughter price levels, pregnancy state of cow, pregnancy test error, and average pregnancy level of herd. Results indicate that the most critical factors are age, pregnancy state, and replacement prices.

"1990 Survey Results of Women Agricultural Economists." Hui-Shung Chang (Auburn University), Mary A. Marchant (University of Kentucky), and Lydia Zepeda (University of Wisconsin)
This poster illustrates the 1990 survey results of the status of women agricultural economists (faculty and graduate students) within the United States, Canada, and Puerto Rico. The survey was conducted by the

Graduate Student Subcommittee of the Committee on Women in Agricultural Economics (CWAE).

"Consideration of Economic Criteria in the Selection of Rice Varieties." Troy N. Thompson, M. Edward Rister, James W. Stansel, Arlen D. Klosterboer, Garry N. McCauley, M. O. Way, N. Glenn Whitney, Fred Turner, Bart Drees, and James W. Richardson (Texas A&M University), Shannon R. M. Pinson, and Charles N. Bollich (USDA)

The acceleration of rice biotechnological breeding efforts suggests improved methods are needed for producers and breeders to rank varieties. The methodology presented here is intended to be useful to scientists planning breeding programs in a multidisciplinary context and for researchers and extension specialists planning educational programs for rice producers.

Award-Winning Theses

Rollins, Kimberly S. "Agriculture and Wildlife: From Principal-Agent Theory to a Wisconsin Economic Policy." Ph.D. thesis, University of Wisconsin, 1990.

Canada geese use Horicon Marsh in central Wisconsin as a rest stop during annual migrations. While in the area, the geese feed on farmland and can cause hundreds of thousands of dollars in damages to crops depending on conditions. At the same time, the geese provide benefits to hunters and other recreationists.

Horicon area farmers, hunters, and wildlife managers have serious doubts about the current wildlife damage abatement and compensation program. Damage abatement is quite labor intensive and is not always successful. Further, farmers' levels of on-farm abatement and the resulting success rates are not observable by wildlife managers. The combined effect of externalities and uncertainty, common to many resource problems, leads to informational asymmetry.

This study views recreational benefit production and costs of feeding geese as a principal-agency problem. The analysis shows how optimal levels of abatement effort and goose use at the marsh are determined theoretically. These findings are used to suggest alternative approaches to address the problem. An economically superior program would leave decisions about abatement effort completely to farmers, base crop damage compensation on mutually observable variables, and more efficiently share risks between farmers and hunters.

Vandeveer, Monte L. "Demand for Crop Insurance and Contract Design: A Case Study for Corn in Indiana." Ph.D. thesis, Purdue University, 1990.

The multiple peril crop insurance (MPCI) program has been criticized as too expensive and not generating sufficient participation to preclude even more expensive disaster payment programs in years of widespread drought. This study examined the effects of four changes in crop insurance: (*a*) improved yield risk classification of farmers, (*b*) better premium setting techniques, (*c*) higher yield guarantees along with coinsurance to offset moral hazard, and (*d*) area yield crop insurance.

Corn farmers in Tippecanoe County, Indiana, were surveyed to get their responses to these changes. A ranked logit model was used to describe farmers' crop insurance decisions as a function of insurance contract features and farmer attributes. Past nonbuyers of MPCI were responsive to the changes mentioned above.

Farmers' responses were then used to compare the relative costs and coverage of a variety of disaster payment and crop insurance programs. Area yield crop insurance and disaster payments triggered by county yield losses were less expensive than programs based on individual yield losses, but they provided less coverage due to the heterogeneity of yield conditions within the county. The performance of crop insurance based on individual yields was substantially improved through the changes mentioned above: a 15% premium subsidy increased participation to 84% at a lower cost than the current MPCI program, where participation has been around 40%.

These results suggest substantial improvement is still possible in the MPCI program. However, making such improvements would require a number of changes, including an overhaul of Federal Crop Insurance Corporation (FCIC) actuarial procedures and more flexibility for the FCIC to set coverage levels. Another important result is that the potential success of area-based disaster assistance depends heavily on the homogeneity of yield conditions within the area, which may limit its effectiveness in some cases.

Zeitouni, Naomi. "Efficient Management of Groundwater Quality: An Evaluation of the Spatially Differentiated Policies." Ph.D. thesis, University of Rhode Island, 1990.

The damage caused by introducing contaminating substances into the groundwater varies spatially due to a variety of site-specific factors. Therefore, uniform strategies, like constant input taxes or other types of fixed regulations, are not economically efficient. This work develops a theoretical framework and an associated empirical model that account for pollution transport.

The methodology is based on a description of the contaminant's migration by partial differential equations that account for physical processes of contaminant transport in porous media. This physical transport model is linked to an economic optimization model to determine efficient means of achieving various policy objectives. The optimization is solved by calculus of variations, yielding a spatially differentiated shadow price equation.

Two applications of the model are considered. First, the model is applied to a case of nitrate fertilization over a heterogenous aquifer. This application examines the role of the variability in aquifer parameters and the water contamination cost in the determination of the optimal policy. Second, the model is applied to find a least-cost means of achieving fixed standards for water quality at well sites by controlling pesticide application to fields.

Ebel, Eric D. "Analysis of the Economics of Pseudorabies Disease in Swine Using a Stochastic Sim-

ulation Model of a Farrow-to-Finish Operation." M.S. thesis, University of Illinois, 1990.

Spurred by plans for the national pseudorabies virus (PRV) eradication program, this research provided estimates of the economic cost of pseudorabies-caused swine production declines. By surveying Illinois quarantined swine herds and developing a stochastic simulation model, varying disease costs were documented for a typical farrow-to-finish operation.

Commercial hog record data were used to estimate distributions for production variables in developing the simulation model. Farrow-to-finish was modeled in ten unique stages. Model output included distributions for net returns per pig, sow and litter, and net annual returns. Various pseudorabies effects were incorporated from the survey results.

Differences in resulting net returns between a baseline scenario and eight separate disease scenarios were tested for statistical significance. EV (expected value, variance) analysis was used to evaluate the economic efficiency of vaccination strategies. Overall, the average cost of pseudorabies across all disease scenarios simulated was estimated at $22.66 per sow per year. However, results also provide estimates of the cost distributions for various disease prevalence levels and vaccination strategies.

Sauder, David. "Simulation of the Tripartite Stabilization Program for Hogs in Saskatchewan Given Rational Expectations." M.Sc. thesis, University of Saskatchewan, 1990.

An econometric model of the Saskatchewan hog economy is constructed. The model is characterized by a supply equation which is discontinuous because of the presence of buffer fund stabilization programs in the province.

The rational expectations assumption of the model implies restrictions on the values of the supply and demand parameters. However, these restrictions cannot be imposed directly because of the discontinuous specification of supply. Instead, the supply and demand parameters are estimated using an iterative procedure which converges to a solution value that satisfies the rational expectations constraints. The iterative loop incorporates a switching function, which chooses the higher of the expected market price and the expected stabilization support price.

The estimated model is simulated using dynamic stochastic simulation to examine the effects of the current Tripartite Stabilization Program. The model suggests significant transfers from taxpayers to hog producers and increases in production leading to price declines. The price effect dilutes the benefit to producers but also provides some benefit to consumers.

Wang, Zhi. "The Effects of Rationing on Consumption Behavior of Chinese Urban Households during 1981–1987." M.S. thesis, Ohio State University, 1990.

This study investigates the impacts of housing, fuel, and food grain rationing on consumption behavior of Chinese urban households. Five variants of the Almost Ideal Demand System with and without rationed goods were estimated using pooled time series (1981–87) and cross-sectional (by income group) data from household expenditure surveys. The empirical results show that rationing of basic living necessities, particularly housing, was one of the important factors that had caused excess demands for nonstaple food and consumer durables. The comparative statics analysis further shows that rationing causes increases in the prices of nonstaple food and household appliances. The estimates from the dynamic model indicate that, if current housing rationing system remains unchanged, Chinese urban households would continue to increase their demand for nonstaple food. This would yield a considerable pressure on food supply for the economy with only 0.1 acre of arable land per capita. Therefore, a reform in housing allocation is suggested as one of the means to remove the distortion of relative prices and reducing the inflationary pressure for nonstaple food in China.

Award-Winning Undergraduate Paper

The North American Hog and Pork Industry: Implications of a Countervailing Duty on Pork

Harry R. Stoddart

During the late 1980s, the National Pork Producers Council (NPPC) in the United States lobbied for and received a countervailing duty (CVD) on pork entering the United States from Canada. The justification for the NPPC's lobby efforts was that the subsidization of Canadian pork production led to more pork entering the U.S. market, which in turn injured U.S. producers. Thus, the NPPC argued that the imposition of a CVD on pork entering the United States would offset the subsidy and counter the damaging effects of the subsidy to the U.S. market. The thinking behind this assumes that a CVD on pork entering the United States would lead to higher U.S. hog prices and, thus, higher revenues for producers. However, the CVD on U.S. hogs causes a shift of the farm-level demand in both Canada and the United States. The shifts in farm-level demand cause shifts of the excess hog demand and excess hog supply curves which intersect to establish the North American hog price. It is the relative magnitude of these shifts which determines whether hog price goes up or down. As shown in figure 1, if Canadian excess supply shifts right more than U.S. excess demand shifts right, then the hog price will drop. Conversely, if Canadian excess supply shifts less than U.S. excess demand, then hog prices will rise. This paper will attempt to determine which scenario is correct and whether or not U.S. producers gained from the imposition of the CVD on pork entering the U.S. from Canada.

Figure 2 presents the theoretical framework for the model. This model is an adaptation of a simultaneous equations model originally estimated by Meilke and Scally. Equations were estimated for farm-level supply and demand and retail demand for Canada and the United States. As well, equations linking the Canadian and American prices of hogs and pork were estimated. The empirical observations for the supply and demand equations started with first quarter, 1969, and concluded with fourth quarter, 1987. Because exports of pork from Canada to the United States did not become significant until the late 1970s, the price linkage equations were estimated over a sample period of 1980:1 to 1987:4.

All prices in the model were deflated by the consumer price index for their respective country. The per capita demand variables were created by dividing the total demand for pork by the total population in the respective country. The natural logarithm of the deflated incomes was taken to impose the restriction of decreasing income elasticities as income increased.

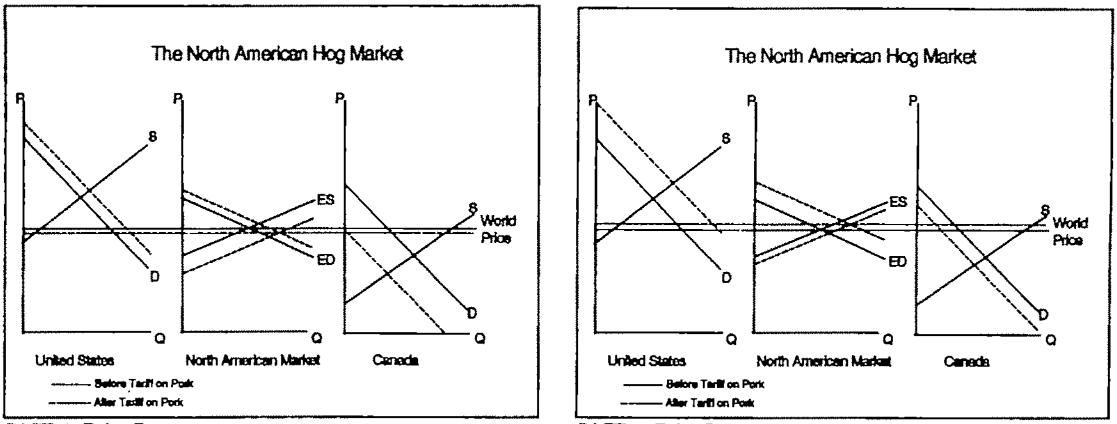
Retail Demand Equations

Economic theory suggests per capita demand for pork is a function of own price, prices of close substitutes, and the level of personal income. However, because the U.S. market faces a very inelastic short-run supply, it is price that adjusts to clear the market instead of quantity. Thus, it follows that a model regressing price on the other factors more realistically describes the situation. As well, a partial adjustment model is suggested when one considers the storability of pork and the imperfect information with which consumers are faced (Meilke and Scally). On the Canadian side, quantity was regressed on price, the prices of substitutes, income, and season. One should expect the price of pork to increase with a decrease in quantity demanded, increase in the price of beef, and an increase in income.

Table 1 presents the final equation estimated over a sample period of 1970:1 to 1987:4. This equation was regressed using the iterative Coch-

Harry R. Stoddart is a senior undergraduate student in the Department of Agricultural Economics and Business, University of Guelph, Canada.

The author wishes to thank James Rude, principal advisor, and Erna van Duren, Larry Martin, Bruno Larue, Karl Meilke, and Jennifer Schroter for their comments and suggestions.



CASE 1: Price Decrease

CASE 2: Price Increase

Figure 1. The effect of a tariff on pork and hog price

rane-Orcutt technique to correct for first-order autocorrelation. The correction for autocorrelation was deemed necessary after running a standard ordinary least squares (OLS) procedure on the same equation yielded a Durbin's h-statistic of 5.16, indicating strong first-order autocorrelation, a fact supported by the rho of 0.93. All signs were as expected. The price of pork rises as the price of beef rises, normal behavior for close substitutes. The positive coefficient for the income variable suggests pork is a normal good. Although insignificant (t-statistic = 0.934), income was left in the equation because microeconomic theory dictates that it should be, and the omission of relevant variables biases the estimates of the other coefficients.

Table 2 presents the Canadian retail demand equation. It has good explanatory powers (ad-

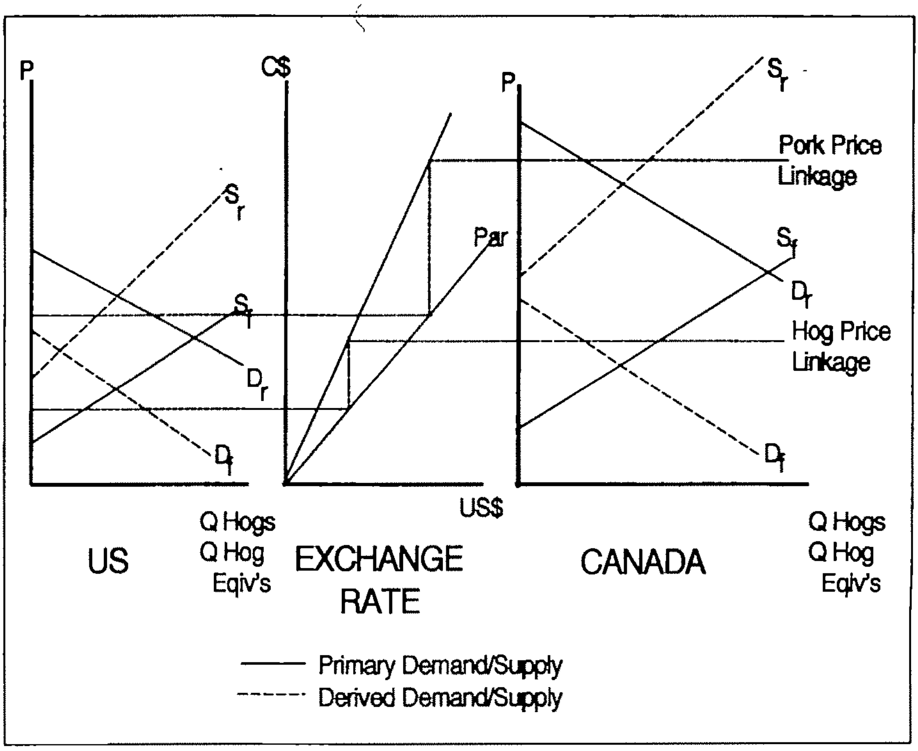


Figure 2. The Model

Table 1. Estimated Equation for U.S. Retail Demand

Dependent Variable: P_{ret}

Variable	Estimated Coefficient	T-Stat	Flexibility Short Run	Flexibility Long Run
Constant	0.677	7.668		
1st quarter dummy	−0.0336	−7.503		
2nd quarter dummy	−0.0568	−11.219		
3rd quarter dummy	−0.0387	−6.722		
Per capita demand	−75.02	−11.235	−12.565	−16.318
P_{beef}	0.447	8.223	8.751	11.365
Ln(*Income*)	0.00672	0.934	0.154	0.200
$P_{ret,t-1}$	0.230	4.251		
Dummy 1973:3	0.0295	2.218		
Rho	0.930	19.570		
Adjusted R-squared	0.848			
F-statistic$_{8,65}$	52.000			
Durbin-Watson	2.419			

justed R-squared = 0.85, F-statistic = 71.16). The Cochrane-Orcutt technique was used to correct a problem with autocorrelation. Otherwise, all variables reacted as expected.

Farm Supply Equations

According to economic theory, the supply of live hogs should be a function of own price, and the prices of significant factors of production. A significant cost of raising a hog to market is the cost of feed. The deflated price of corn was used as a proxy for the feed costs. An adaptive expectations model was used to reflect the fact that it is not a current price which a farmer bases his production decision upon but rather an expected price based upon all past prices (Nerlove). The geometrically declining lag structure imposed by a lagged dependent variable (LDV) was used to approximate this situation. One should expect the supply of hogs to increase with its own price and decrease with the price of corn.

Because production decisions are made *ex-ante*, prices were lagged one complete year to allow for six-month-old animal being marketed, the gestation period of a pig (3 months, 3 weeks, and 3 days) and a reasonable time to implement production decisions.

Table 3 presents the final equation that was estimated over a sample period of 1970:1 to 1987:4. The model was regressed using a standard OLS estimation technique because autocorrelation was not a problem (Durbin h-statistic = 0.37). All signs were as expected and all variables were significant. The supply of hogs was found to rise with an increase in the price of hogs and fall with an increase in the price of corn. This model has relatively good explanatory power because all variables are significant and behave as expected, and it has a substantial adjusted R-squared of 0.85 and an F-statistic of $68.79_{[6.65]}$.

Table 2. Estimated Equation for Canadian Consumer Demand

Dependent Variable: *Per Capita Demand$_{ret}$*

Variable	Estimated Coefficient	T-Statistic	Elasticity
Constant	0.00477	5.518	
P_{ret}	−0.00706	−14.808	−0.977
P_{beef}	0.00249	6.809	0.362
Ln(*Income*)	0.00211	8.446	0.385
1st quarter dummy	−0.0000424	−0.604	
2nd quarter dummy	−0.000570	−7.478	
3rd quarter dummy	−0.000716	−10.136	
Rho	0.274	2.471	
Adjusted R-squared	0.851		
Durbin-Watson	1.971		
F-statistic$_{6,68}$	71.165		

Table 3. Estimated Equation for U.S. Hog Supply

Dependent Variable: $Supply_{farm}$

Variable	Estimated Coefficient	T-Statistic	Elasticity Short Run	Elasticity Long Run
Constant	4676.4	3.772		
$P_{farm,t-4}$	10830.0	4.704	0.106	0.855
$P_{corn,t-4}$	−4075.0	−4.908	−0.092	−0.742
$Supply_{farm,t-1}$	0.876	16.713		
1st quarter dummy	−3428.4	−11.604		
2nd quarter dummy	−2457.9	−9.014		
3rd quarter dummy	−3374.0	−12.167		
Dummy 1973:3	−2290.2	−2.801		
Adjusted R-squared	0.866			
F-statistic$_{7,64}$	66.292			
Durbin's h-statistic	0.371			

Table 4 presents the Canadian equation. An OLS technique was used since autocorrelation was not a problem. All variables reacted as expected. The explanatory power of this equation can be considered quite good (adjusted R-squared = 0.98, F-statistic = 457.5).

Processor Demand for Hogs

This section of the paper develops and discusses an equation for processor demand for hogs. Theory tells us that processor input demand is a function of the price of the input in question, price of other inputs, and the price of the output(s). Thus, it follows that an equation which regresses hog slaughter on the price of hogs, price of pork, and wages in the U.S. meat-packing sector should accurately describe the situation. Theory also allows for more elastic demand in the long run than the short run because of the inflexibility of wage contracts and capital investments. Thus, an equation allowing for differing long- and short-run elasticities, such as the partial adjustment model; should be used. If one considers the decision to build a plant and hire staff as the production decision, then a partial adjustment model is justified. However, if one considers the production decision as being made each morning based on current prices, then the partial adjustment model is not justified. Meilke and Scally chose the latter route in the development of their model; I chose the former. Regardless of which theory one subscribes to, processor demand should rise with an increase in the price of pork, a decrease in the price of hogs, and a decrease in the wage rate.

Meilke and Scally left out the partial adjustment process and turned the model around and estimated price based on quantity. Their justification for this model was the relative inelastic demand curve and the fact that there are very few channels for hogs to come through as well as little room for quantity to adjust; therefore, they theorized that price adjusted to clear the market.

Table 4. Estimated Equation for Canadian Hog Supply

Dependent Variable: $Supply_{farm}$

Variable	Estimated Coefficient	T-Statistic	ELASTICITY Short Run	ELASTICITY Long Run
Constant	146.71	1.033		
$P_{corn,t-4}$	−157.97	−3.942	−0.074	−37.00
$P_{farm,t-4}$	124.54	2.871	5.774	2887.00
$Supply_{farm,t-1}$	0.998	36.289		
1st quarter dummy	−24.024	−0.690		
2nd quarter dummy	−188.12	−5.304		
3rd quarter dummy	−258.69	−7.250		
Adjusted R-squared	0.975			
Durbin's h-statistic	−0.587			
F-statistic$_{6,65}$	457.492			

Table 5. Estimated Equation for U.S. Hog Demand

Dependent Variable: $Demand_{farm}$

Variable	Estimated Coefficient	T-Statistic	Elasticity	
			Short Run	Long Run
Constant	8903.7	4.089		
P_{farm}	−35907.	−6.214	−0.348	−0.763
P_{ret}	8180.9	1.972	0.254	0.557
$Wage_{processor}$	3070.7	3.273	0.199	0.436
1st quarter dummy	−2221.4	−7.817		
2nd quarter dummy	−1868.5	−8.717		
3rd quarter dummy	−2332.9	−10.651		
$Demand_{farm,t-1}$	0.544	6.686		
Dummy 1973:3	878.72	1.273		
Adjusted R-squared	0.921			
F-statistic$_{8,66}$	109.157			
Durbin's h-statistic	1.227			

The only lagged variable in the model is the dependent variable needed to set up the partial adjustment model with a geometrically declining weight structure.

Table 5 presents the final equation estimated over a sample period of 1970:1 to 1987:4. Because autocorrelation was not a problem (Durbin h-statistic equal to 1.66), an OLS regression technique was used. The adjusted R-squared of 0.921, F-statistic of $109.16_{[7,68]}$, and all variables being significant at the 95% level indicate a relatively high degree of explanatory power. This is a definite contrast to the regression results (not presented) when I attempted to duplicate Meilke and Scally's equation. While the R-squared and F-statistic were significant, only the coefficient on the price of pork and the price of hogs were significant. Thus, the possibility of multicollinearity was quite high. As well, autocorrelation became a problem that needed to be corrected (Durbin h-statistic = 7.14), which raises questions about whether all relevant variables were included.

The equation presented in table 5 has no serious contradictions with economic theory except the positive sign on the wage term. This may indicate a multicollinearity problem; however, it was left in the equation to avoid bias problems. All other signs were as expected. Demand rose with an increase in the price of pork and a decrease in the price of hogs.

Table 6 presents the Canadian processor demand equation. Its structure is identical to the U.S. demand equation, and its results are similar. Once again, the wage term has a positive coefficient. Although insignificant, it was left in to avoid bias problems associated with omitted relevant variables.

Table 6. Estimated Equation for Canadian Hog Demand

Dependent Variable: $Demand_{farm}$

Variable	Estimated Coefficient	T-Statistic	Elasticity	
			Short Run	Long Run
Constant	118.65	0.506		
P_{farm}	−303.01	−4.423	−0.191	−1.447
P_{ret}	851.01	2.799	0.238	1.803
$Wage_{processor}$	75.360	1.110	0.095	0.720
$Demand_{farm,t-1}$	0.868	26.158		
1st quarter dummy	−56.889	−1.741		
2nd quarter dummy	−193.05	−5.805		
3rd quarter dummy	−242.61	−7.306		
Adjusted R-squared	0.973			
Durbin's h-statistic	0.536			
F-statistic$_{7,67}$	393.475			

Table 7. Estimated Equation for the Hog Price Linkage

Dependent Variable: *CAN* P_{farm}

Variable	Estimated Coefficient	*T*-Statistic	Flexibility Short Run	Flexibility Long Run
Constant	6.861	0.335		
($U.S.$ P_{farm}-*Tariff*)* Exchange rate	2.288	13.487	3.283	3.927
CAN $P_{farm,t-1}$	0.164	2.084		
Rho	0.809	6.319		
Adjusted *R*-squared	0.863			
Durbin-Watson	1.870			
F-statistic$_{2,28}$	95.557			

Price Linkage Equations

Tables 7 and 8 present the equations estimated to link Canadian prices to American prices. This estimation was performed because Canadian prices are set in the U.S. market. As can be seen from the results, these equations have high degrees of explanatory power (both R-squared's > 0.80). The equations regress Canadian price on the U.S. price less any tariffs multiplied by the exchange rate and a lagged dependent variable. The LDV was included to allow for the fact that there is a lagged adjustment process (Meilke and Scally).

The Simulation

The eight estimated equations were combined with eight identities to form a closed model. Thus, the equations and identities used were as follows:
Canadian equations and identities:

$$Demand_{ret} = f(Price_{ret}, Price_{beef}, Income, Season)$$

$$Demand_{farm} = f(Price_{ret}, Price_{farm}, Wages, LDV, Season)$$

$$Supply_{farm} = f(Price_{farm}, Price_{corn}, LDV, Season)$$

$$Price_{ret} = f(U.S.\ Price_{ret} * exchange\ rate, LDV)$$

$$Price_{farm} = f([U.S.\ Price_{farm} - Tariff] * exchange\ rate, LDV)$$

$$Supply_{ret} \equiv Demand_{farm} * hog\ carcass\ weight$$

$$Supply_{farm} \equiv Demand_{farm} + Exports_{U.S.}$$

$$Supply_{ret} \equiv Demand_{ret} + Exports_{U.S.} + Exports_{ROW} + \Box Inventory$$

$$Total\ Demand_{ret} \equiv Per\ Capita\ Demand_{ret} * Population.$$

Table 8. Estimated Equation for the Pork Price Linkage

Dependent Variable: *CAN* P_{ret}

Variable	Estimated Coefficient	*T*-Statistic	Flexibility
Constant	20.536	0.727	
$U.S.$ P_{ret}* *Exchange* rate	0.356	11.289	0.265
Rho	0.957	12.124	
Adjusted *R*-squared	0.813		
Durbin-Watson	2.116		
F-statistic$_{2,28}$	66.344		

American equations and identities:

$$Demand_{ret} = f(Price_{ret}, Price_{beef}, Income, LDV, Season)$$

$$Demand_{farm} = f(Price_{ret}, Price_{farm}, Wages, LDV, Season)$$

$$Supply_{farm} = f(Price_{farm}, Price_{corn}, LDV, Season)$$

$$Supply_{ret} \equiv Demand_{farm} * hog\ carcass\ weight$$

$$Supply_{farm} \equiv Demand_{farm} - Imports_{CAN}$$

$$Supply_{ret} \equiv Demand_{ret} - Imports_{CAN} + Exports_{ROW} + \Delta Inventory$$

$$Total\ Demand_{ret} \equiv Per\ Capita\ Demand_{ret} * Population$$

The endogenous variables are as follows:

U.S. $Price_{ret}$
U.S. $Price_{farm}$
U.S. Per Capita Quantity $Demanded_{ret}$
U.S. Total Quantity $Demanded_{ret}$
U.S. Quantity $Supplied_{ret}$
U.S. Quantity $Demanded_{farm}$
U.S. Quantity $Supplied_{farm}$
CAN $Price_{ret}$
CAN $Price_{farm}$
CAN Per Capita Quantity $Demanded_{ret}$
CAN Total Quantity $Demanded_{ret}$
CAN Quantity $Supplied_{ret}$
CAN Quantity $Demanded_{farm}$
CAN Quantity $Supplied_{farm}$
CAN Hog Exports to U.S.
CAN Pork Exports to U.S.

Statistics comparing the results of the simulation and the actual values are presented in table 9. Graphing the actual and simulated values revealed no major misses in terms of turning points. All variables except hog and pork exports from Canada to the United States were simulated with reasonable accuracy.

Impact of the Countervailing Duty: A 3% Duty on Pork Entering U.S.

The model was then shocked by creating a 3% price wedge between Canadian and American pork prices. This is an approximation of the actual countervailing duty placed on pork entering the United States from Canada. The tariff was incorporated into the pork price linkage equation as follows:

$$Price_{ret} = \beta_0 + \beta_1(\text{U.S. } Price_{ret} * \text{exchange rate} * .97) + \beta_2\, Price_{ret}(-1).$$

The simulation was then resimulated from 1980:1 to 1987:4. Table 10 summarizes the changes relative to the original simulation over the period 1981:1 to 1987:4. The year 1980 was

Table 9. Simulation Summary Statistics

Variable	Correlation Coefficient Squared United States	RMPSE*	Correlation Coefficient Squared Canada	RMPSE
Per capita consumption	0.533	5.2	0.365	12.7
Total retail demand	0.620	5.2	0.694	12.7
Retail supply	0.556	5.4	0.316	15.3
Farm demand	0.570	5.2	0.125	15.2
Farm supply	0.613	5.4	0.852	4.8
Retail price	0.883	8.7	0.900	21.2
Farm price	0.633	14.4	0.642	16.9
Hog exports to U.S.	N/A		0.455	551.6
Pork exports to U.S.	N/A		0.223	208.2

Note: $RMSPE = \dfrac{\sum_{1}^{n} \sqrt{\left(\frac{(simulated-actual)}{actual}\right)^2}}{n}$

Table 10. CVD Effects, Percent Change in Variables

Variable	Canada	United States
Per capita consumption	2.02*[a]	−0.02
Consumer demand	2.02*	−0.02
Processor supply	−2.65*	0.68*
Processor demand	−2.68*	0.24*
Farm supply	−0.28**	−0.21*
Pork price	−2.37*	0.03
Hog price	−0.39*	−0.37*
Trade from Canada		
Hogs to U.S.		29.81*
Pork to U.S.		−10.84*

[a] Single asterisk denotes significance at 1% level; double asterisk denotes significance at 10% level.

excluded from these results to allow for the four-quarter lag in the primary supply equations.

Discussion and Implications

The results of the imposition of the CVD presented in table 10 indicate that the scenario of the Canadian excess supply curve shifting more than the U.S. excess demand curve is the correct description of this situation. Because U.S. farmers are shipping 0.21% less hogs and receiving a price that is 0.37% less with the CVD in place as compared to the same time period without it, their revenues have decreased 0.58%. The imposition of a CVD does not alter the cost structure of the industry. Thus, producers revenues have decreased and costs remained constant, implying their welfare decreased. Producer surplus would have been a better measure of the change in producer welfare. However, because of the lag structure employed in the model, it was not clear which supply curve should be used to measure producer surplus over. Thus, change in producer revenue is used as an approximation for the change in producer welfare.

Limitations

This model has two problems which limit the usefulness of its results. The first problem is its inability to accurately describe trade in hogs and pork. This problem should not bias the results and conclusions to any great degree because the behavior of the farm-level supply and demand curves determine the price levels; these curves simulated with a reasonable degree of consistency. The second problem is the time period over which the equations were estimated versus the time period over which the actual CVD was implemented. Structural changes in the North American hog/pork industry likely occurred between 1969 and 1988, when the actual CVD was imposed. Thus, the model may not accurately describe the situation in which the CVD was implemented.

Further research should be directed to updating this model with data from 1988 to 1991. Once the model is updated, it would be interesting to determine if the results hold for the actual time period in which the CVD was implemented.

References

Meilke, K. D., and M. Scally. *Trade in Vertically Related Markets: The Case of Hogs and Pork.* Dep. Agr. Econ. and Bus., Work. Pap. WP88/17, University of Guelph, 1988.

Nerlove, M. "Estimates of the Elasticities of Supply of Selected Agricultural Commodities." *J. Farm Econ.* 38(1956):496–509.

Abstracts

"Demand Relationships for Table Wine in Texas and the Influence of the Emerging Texas Wine Industry." Jason Johnson (Texas Tech University), second-place paper.

The Texas wine industry is growing in terms of its stature and prominence within the agricultural economy of the state. Texas and U.S. per capita consumption patterns of table wine have differed over the past twenty years. The objective of this study was to identify factors that explain changes in table wine consumption in Texas. A log linear wine consumption function was used, and regression analysis was performed using the ordinary least squares technique. Income and a time trend were found to be significant variables. A dummy variable was added to measure the influence of an emerging Texas wine industry. A systematic process was used to identify 1980 as the threshold year of industry emergence within a range specified by grape growers and wine producers. The explanatory power of the model increased dramatically with the dummy variable added to the income and time trend variables. The implications of this research suggest that it is reasonable to attribute the difference in U.S. and Texas consumption trends to an emerging Texas wine industry. The Texas emerging wine industry has not only created interest in its own production but has increased the demand for all table wine.

"Economic Feasibility of an Insectary in the Pacific Northwest." Donald R. Gephart (Washington State University), third-place paper.

The age of total chemical control is fast coming to an end. New laws, cost of chemicals, and the resistance of pests to chemicals have all marked the end of the chemical age for agriculture. Out of this age comes an increased interest in the "old method" of biological control. Special interest has been made in the mass rearing and distribution of parasitoids. There have been numerous examples of successful releases; however, more research needs to be accomplished at the local level for proper control on a permanent basis as well as a seasonal basis in certain crops. This feasibility study shows that an insectary is a feasible alternative source of pest control in the Pacific Northwest.

Committee Reports

Report of the President

We, as an association, have evolved considerably since our founding, and I believe that the membership will see in this year's activities and program a conscious effort to reflect the many increased facets of our, and other allied, subdisciplines, as well as the diversity of both group and individual interests within the agricultural economics profession.

We are all aware of the economic conditions which might have impacted registration at these annual meetings. I am pleased to report that the professional member registration is comparable to the registration realizations at our most recent U.S. university-based meeting, at Louisiana State University in 1989 and the Knoxville meetings in 1988. We are, understandably, very pleased with the registration numbers. Our hosts at Kansas State University have provided us with an excellent venue for our meetings. Excellent facilities contribute much toward the quality of both professional and social experiences.

Those who know me well know that I am often wont to say "Time goes fast when you're having fun." The year has passed rapidly, and we have accomplished much. We have selected new editors, seen an opening of association services and activities, pursued efforts to increase understanding of the association by the membership, applauded the emergence of meaningful activities supported by the AAEA Foundation, assisted the development of a wide variety of activities and programs by association committees now permitted to operate more entrepreneurially with board approval, and enjoyed an improved system of financial accounts which permits better planning discussions and actions.

I have, throughout the year, reported to the membership (in *AAEA Newsletter*) actions taken to open programs of the association to more diverse interests of individuals and groups. We have made changes in operations and programs very much in the spirit of adaptive planning with the goal of improving association services to the membership and enhancing membership numbers. I have received comments, pro and con, about our announced actions, and they have been useful in guiding board deliberations. As in all ventures involving elected officials where there is serious effort made to serve the electorate, we are eager to receive your comments on actions taken and your suggestions for improvements.

The expansion of services and programs, including support of association publications and activities, is becoming increasingly complex and demanding of the board and the AAEA Business Office. We are extremely well served by the Iowa State-based business office, and some increase in staffing may be required to support our expanding agendas. Ray Beneke's announced intention to step down as AAEA Secretary/Treasurer at the end of the coming year requires that the board consider replacement and/or identify organizational alternatives to support current and possible future programs of the association. Such decisions are not to be made lightly for the continuation of association services and financial balance are important considerations. A reduced membership also makes marked change more problematic. A subcommittee of the board will examine our needs and report its recommendations later this year. The board will bring any discussion of organizational change to the association's next annual business meeting in Baltimore.

While we have been extremely successful, in my opinion, in opening ourselves to involvement with associations, societies, and emerging interest groups, we are less confident in our ability to enter into arrangements which would foster and support national research agendas and priorities or would increase access to public funds commitments. Many would involve us more actively than we have been thus far, and there has been very recent criticism of our hesitancy to move this association toward stronger advocative strategies. The challenges will surely involve board discussion in the coming year.

These annual meetings, our annual summer family picnic, are the result of massive efforts, not only of association officers and business office staff, but also of association committees and individual members. To name all who have made meaningful contributions would be impossible, but to each of you we express our collective thanks for your contribution and assistance.

We, in the American Agricultural Economics Association, frequently cosponsor our meetings with allied associations. The Association of Environmental and Resource Economists has again contributed sessions to our summer program, and so I wish to acknowledge contributions by members of AERE and 1990–91 AERE President Chuck Howe, of the University of Colorado.

This year you will find in the program sessions involving several allied associations including the Agricultural History Society and the newly founded International Agribusiness Management Association. The preconference of the Social Science Agricultural Agenda Project was cosponsored with the Rural Sociological Society and the Agricultural History Society.

Occasionally, we share sponsorship with other U.S. regional associations or with the Canadian Society

when we are in the neighborhood, as we were last year. Previous presidents Joe Havlicek and Sandra Batie tell me that "Peace Pipe Smoking" is a sort of special Olympic qualifying event which we schedule only every four years or so, to my great relief!! However, we will continue to pursue cosponsorships with appropriate societies in the coming years. Our 1992 meeting in Baltimore will be cosponsored with the Northeastern association and will be held in conjunction with the annual meetings of the Soil and Water Conservation Society. Our 1993 meeting in Orlando, Florida, may be cosponsored with the Caribbean Agro-Economics Society and with the Rural Sociological Society. Our 1994 meeting in San Diego, California, will be cosponsored with the Western association and the National Institute of Agricultural Economics of Mexico, also likely cosponsors of our 1996 meetings in San Antonio, Texas. We have interacted with these allied associations throughout this year, and they are represented in the registered membership of these meetings.

International dimensions of our profession are increasing with ease of transportation and communication. In the past year we have gained improved relations with the important European Association of Agricultural Economists, including the announcement of EAAE events in our *AAEA Newsletter*. The American Agricultural Economics Association is a cosponsor of 1992 Conference in Beijing, China, with the PRC Agricultural Economics Association of China and the Taiwan Rural Economics Society of China. We are a cosponsor of the U.S. invitation for hosting the triennial meetings of the International Association of Agricultural Economists in 1994. That proposal will be made to the IAAE Executive group in Tokyo later this month.

We wish, also, an especially warm welcome to the annual meetings for two groups in attendance at these meetings. Last fall, our secretary-treasurer, Ray Beneke, conceived of an opportunity to invite professionals in newly democratized economies of Eastern Europe and the USSR. His objective has been to provide an experience whereby participants might examine the role of professional associations of agricultural economics as part of the development strategy in the transition from centrally planned to market economies. Through his efforts we have twelve representatives with us from Hungary, Czechoslovakia, Poland, and the USSR. Our China committee also is hosting a delegation from the People's Republic of China. To these and others of the international community in our midst, we welcome you and encourage you to invite your colleagues to future annual meetings of the American Agricultural Economics Association.

I owe thanks to many. I thank the membership for their implicit trust and confidence. I hope I have served you well.

I thank my colleagues at Davis for their support and patience while I pondered concerns, even east of the Sierra Nevada's.

The AAEA Business Office, especially Lona Christoffers, Charlene Carsrud, and Secretary-Treasurer Ray Beneke have always been calm and of great assistance.

My appreciation is also extended to all executive board members and editors. They have been marvelous to work with, and their deliberations have always been considered and fair. I salute their professionalism and acknowledge the friendship and professional respect that has grown as we have interacted in board room and in too-infrequent purely social interactions.

Three years ago this association elected three individuals to the executive board for terms which expire at the end of these meetings. They deserve special recognition in this report.

Walter Armbruster has been an effective and hard working director. As chairperson of the board's Finance Committee, he has been particularly effective in implementing improved financial record keeping in the business office and has played an important role in other association innovations. We wish him continued success as director-designate of the Farm Foundation, and we anticipate continued, significant contributions to the support of social sciences in agriculture.

Gene Futrell's untimely death earlier this year was a loss not only to his personal family, but also to his family of agricultural economists. We knew him for only a short period, and he was a thoughtful, reasoned voice around our board table. Like his family, we, too, miss him.

To Sandra Batie, my predecessor, I owe a special thanks for helping share the burdens of my initial short term as president-elect and for providing assistance and wise counsel during this year. She now leaves the executive board. Her participation and leadership, as director and president, have been instrumental in the continued development of this association, particularly with respect to its adaptive planning and economic education initiatives. We acknowledge her long and effective service to the association and wish her continued success.

The thoughtful assistance of many unnamed others have helped with speeding the passage of time. The time has indeed flown. I have been honored to serve as president of the American Agricultural Economics Association.

Warren E. Johnston, president

Report of the Secretary-Treasurer

The association ended 1990 with a net income of \$89,430. This included investment income and gain on sale of stock of \$141,332. As we evaluate these financial results, it is important that we bear in mind that 1990 was truly an exceptional investment year.

Although our 1991 budget, prepared in 1990, anticipated a shortfall of \$69,900, based on the infor-

mation we now have, we are projecting a 1991 deficit of about $55,000. My guess is that the deficit will be less than that projected. In any case, it will not be so great as to threaten the financial health of the association.

In interpreting 1991 financial results, the reactors should bear in mind that there were two expense items paid in 1991 that typically are incurred every three to five years. One is the cost of transferring the *Journal* editorship, a $25,000 item. The second is the publication of a new *AAEA Handbook Directory* at a cost of about $21,000.

The readers will recall that we raised our membership dues for regular members from $45 to $60, with comparable increases in other categories. We had 45 fewer regular members on 30 June 1991 than on the same date in 1990. This is a decline of about 2%. The decline in junior members was somewhat greater, although the significance of the decrease is more difficult to interpret. This arises out of the fact that graduate students joined the association in larger numbers in 1990 in connection with attending the summer meetings, thus complicating the interpretation of 1991 to 1990 comparisons.

I believe the organization should put greater emphasis on membership procurement than it has during the last two or three years. We often see evidence of people who should be members but for one reason or other are not.

The board raised *Journal* subscription prices modestly, which should increase 1992 and 1993 income somewhat.

Income and expense projections for 1992 and 1993 indicate that we should be operating in the black during these years.

I have said nothing of the Foundation's financial progress. I am pleased to note that Ken Farrell will be providing you with a positive report.

Raymond R. Beneke, secretary-treasurer

Report of the Tellers Committee

Ballots for the elections of the AAEA Executive Board and the AAEA Foundation Governing Board were sent to and collected from the association members by the AAEA Business Office and secretary-treasurer and counted by the Tellers Committee in accordance with the constitution and bylaws.

The successful candidates were:

President-elect:	James P. Houck
Directors of the executive board:	Ralph D. Christy Eileen O. van Ravenswaay
Members of the Foundation governing board:	George E. Rossmiller Susan E. Offutt

A total of 3,642 packets of election materials were mailed to eligible members, compared to 3,924 in 1989 and 3,826 in 1990. There were 1,857 ballots returned by the 15 June deadline for a response rate of 50.9%. The response rate was up from the approximate 46% level of the previous year. All ballots returned before the deadline were counted except for 15, which were spoiled. Also, 12 ballots received after the 15 June deadline were not counted.

Ronald Dieter, chairperson

Report of the AAEA Finance Committee

During the past year the Finance Committee has worked to revise the budget format to make as clear as possible the income and expenses for each of the major AAEA activities. Budget projections for the next two years will help identify potential problems before they reach a critical stage.

As shown in table 1, during the 1990 calendar year operating expenses exceeded operating income by approximately $42,500. Investment income of $66,000 and investment expenses of $10,000 resulted in net income of $14,300. In addition, $75,000 in capital gains were realized from the investment portfolio. Action was taken at last year's annual meeting to increase dues to provide greater operating revenue during 1991. The board also adopted a policy permitting the budgeting for expenses of up to 3% of the average past three year-end portfolio value.

At this meeting, the board increased library subscriptions for the AJAE from $65 to $90, the first increase in some years. The hypothesis is that we face an inelastic demand, especially since our price will still be quite low compared to many journals. The proposed 1992 budget has been adopted by the board. It and the proposed 1993 budget both project net income.

AAEA's investment portfolio market value decreased during calendar year 1990 by 1.6% to $965,000 compared with $981,000 as of 31 December 1989. It has since increased to $1,058,000 as of the 28 June 1991 end of the second quarter and is invested roughly as follows:

Income account:	Short-term investments	10%
Principal account:	Bonds	30%
	U.S. equity (index)	20%
	Active equity (value)	40%

Performance comparisons since 1985 indicate that AAEA's portfolio management has returned an average of approximately 2.5% less than the median of 450 fund managers polled by the Pensions and Investments Performance Evaluation Report. A 2.5% underperformance implies $25,000 lower income, or more than $5.00 per member per year. Therefore, I recommend that the Finance Committee explore investment management alternatives.

I also reviewed the auditor's report and conferred with Lona Christoffers regarding actions taken to comply with recommendations made by the auditor relative to operating procedures dealing with financial management and tracking.

I would like to thank committee members: Kitty

AAEA Membership and *AJAE* Subscriber Numbers

	Total 1988	6-30-89	Total 1989	6-30-90	Total 1990	6/30/91	Total 1991	Average 1988–91
U.S.								
Senior	212	221	220	213	217	204	204	213
Regular	2,784	2,572	2,701	2,493	2,694	2,450	2,450	2,657
Junior	670	515	625	588	676	488	488	615
Family	30	28	29	30	31	26	26	29
Lifetime	47	52	52	57	56	58	58	53
Total U.S.	3,743	3,388	3,627	3,381	3,674	3,226	3,226	3,568
Industry	23	23	25	15	15	15	15	20
AJAE subscribers	690	2,337	2,362	673	692	644	644	1,097
CANADA								
Senior	9	8	8	8	8	8	8	8
Regular	179	164	184	174	199	165	165	182
Junior	39	29	41	33	58	22	22	40
Family	1	1	1	0	0	0	0	1
Lifetime	1	1	1	2	2	2	2	2
Total Canada	229	203	235	217	267	197	197	232
Industry	1	1	1	2	4	1	1	2
AJAE subscribers	73	73	74	66	66	61	61	69
FOREIGN								
Senior	18	18	18	18	18	16	16	18
Regular	567	520	572	509	562	512	512	553
Junior	30	25	40	25	41	19	19	33
Family	0	0	0	0	0	2	2	1
Lifetime	7	9	9	10	10	10	10	9
Total foreign	622	572	639	562	631	559	559	613
Industry	0	0	0	0	0	1	1	0
AJAE subscribers	1,001	839	949	853	933	864	864	937
Total members	4,618	4,187	4,527	4,177	4,591	3,999	3,999	4,434
Total individual members	4,594	4,163	4,501	4,160	4,572	3,982	3,982	4,412
Total Senior	239	247	246	239	243	228	228	239
Total Regular	3,530	3,256	3,457	3,176	3,455	3,127	3,127	3,392
Total Junior	739	569	706	646	775	529	529	687
Total Family	31	29	30	30	31	28	28	30
Total Lifetime	55	62	62	69	68	70	70	64
Total Industry	24	24	26	15	19	17	17	22
Total Reference Room		32	32	24	25	26	26	28

Table 1. Abbreviated Budgets, 30 June 1991

	1990 Budget	1990 Actual	1991 Budget	1991 Year to Date	Proposed Budget 1992	Proposed Budget 1993
OPERATING INCOME						
MEMBERSHIP DUES	$188,460	$196,728.84	$250,000	$222,114.43	$239,900	$251,900
MEETINGS	5,000	155,184.35	7,500	42,598.26	120,000	120,000
AJAE	179,000	188,576.54	166,000	148,576.45	166,000	172,000
Newsletter	18,800	22,613.00	17,800	8,645.25	16,700	17,300
Choices	80,000	93,643.01	72,000	46,031.03	75,000	80,000
EMPLOYMENT SERVICE	300	304.95	300	0.00	300	300
Other	10,040	12,387.62	11,260	3,608.81	8,010	8,010
TOTAL OPERATING INCOME	$481,600	$669,438.31	$524,860	$471,574.23	$625,910	$649,510
Investment Income	51,000	66,212.72	49,000	30,149.61	46,000	46,000
TOTAL OPERATING INCOME INCL. INVESTMENT INCOME	$532,600	$735,651.03	$573,860	$501,723.84	$671,910	$695,510
Gain on Sale of Stock	39,500	75,119.09	0	5,982.05	29,181[a]	29,181[a]
TOTAL OPERATING INCOME PLUS CAPITAL GAINS	$572,100	$810,770.12	$573,860	$507,705.89	$701,091	$724,691
OPERATING EXPENSE						
PROJ, COMM, MBR SERV	15,740	16,180.62	33,260	14,226.07	17,500	17,500
MEETING	500	147,945.46	500	19,168.87	110,000	110,000
EXECUTIVE BOARD	18,000	13,803.13	22,500	8,927.91	20,000	20,000
EMPLOYMENT	14,000	19,700.89	15,000	4,475.34	16,700	16,700
BUSINESS OFFICE	95,100	95,765.71	102,200	54,943.06	105,600	109,400
AJAE	212,000	225,635.06	234,200	103,205.25	209,200	209,200
Newsletter	21,100	29,246.90	21,100	15,285.95	25,500	26,500
Choices	166,000	130,376.69	180,000	71,564.01	188,000	196,000
Other	29,500	32,793.75	25,500	19,351.40	30,350	30,800
TOTAL OPERATING EXPENSE	$571,940	$711,448.21	$634,260	$311,147.86	$722,850	$736,100
INVESTMENT EXPENSE	9,500	9,891.95	9,500	5,520.40	10,000	10,000
TOTAL EXPENSE INCL INVESTMENT EXP	$581,440	$721,340.16	$643,760	$316,668.26	$732,850	$746,100
Net Income (Loss)	($90,340)	($42,009.90)	($109,400)	$160,426.37	($96,940)	($86,590)
Net Income (Loss) Incl Investment	($9,340)	$89,429.96	($69,900)	$191,037.63	($31,759)	($21,409)

[a] Equals 3% of the average market value of the portfolio for the last 2 years ending 12/31.

Table 2. Combined Funds Balance Sheet, 31 December 1989/90

	A	B	C
1	COMBINED FUNDS BALANCE SHEET, Dec. 31	1990	1989
2	Current Assets	($)	
3	Operating accounts (cash)	369,910	301,622
4	Am. National Bank (portfolio @ cost)	924,214	846,002
5	Accounts receivable, prepaid expenses	24,162	41,794
6	**Total current assets**	1,318,286	1,189,418
7	Property and equipment	5,769	7,544
8	**Total assets**	**1,324,055**	**1,196,962**
9			
10	Current Liabilities	290,845	294,122
11	Equity		
12	General fund	838,501	562,772
13	Choices fund	0	188,568
14	AAEA Foundation funds	129,104	103,525
15	Kellogg grant funds	45,600	32,975
16	Other restricted funds	20,005	15,000
17	**Total equity**	1,033,210	902,840
18	**Total liabilities & fund balances**	**1,324,055**	**1,196,962**
19			
20	Market value adjusted lines		
21	Portfolio at market value (see line 4)	964,778	980,575
22	Total assets at market value (see line 8)	1,364,619	1,331,535
23	General fund at market value (see line 12)	879,065	697,345
24	**Total equity at market value (see line 17)**	**1,073,774**	**1,037,413**

Reichelderfer, vice-chair; Ray Beneke, David Barkley, Steve Hanson, David Kohl, Mike Mazzocco, and Eddy LaDue for their assistance with Finance Committee Activities during the past year. I would also like to thank Ray Beneke and Lona Christoffers for their efforts in revising the budget formats and keeping the board informed of the AAEA financial status.

Walter J. Armbruster, chairperson

Report of the *AJAE* Editor (1990–91)

This report marks the close of the fifth and final year of operations for the Illinois editorial office of *AJAE*. In February of 1991, the transfer of manuscript handling to the new coeditors (Steve Buccola and Rich Adams) was completed, and the remaining major tasks for me were to publish the December proceedings issue, select the 1990 outstanding journal article, oversee the printing of the 1991 issues of the *Journal*, and handle other administrative details. The transfer to the new coeditors was a very smooth one, and they will do an excellent job with the *Journal*.

New submissions of manuscripts continued to increase, reaching a record total of 391 manuscripts during the most recent twelve-month period of manuscript handling in the Illinois office. The total number of new submissions over the five-year period was 1,742, or 348 per year. We have continued to emphasize timeliness in the handling of manuscripts, as indicated by the frequency distribution and averages of handling times for the various submission categories of manuscripts and reviewers reported in table 1. During the last twelve months of manuscript handling, the response time on the original submission averaged 70 days, with a response of 78% occurring within a 90-day period, 93% within a 120 day period, and 100% within 150 days. The average response times on second and third submissions were 33 days and 9 days, respectively. Over the entire five-year period the average response times were 71 days on the original submission, 31 days on the second submission, and 8 days on the third submission.

During 1991, we will publish 108 articles, 9 comments, and 8 replies in volume 73 of the *Journal*, for a total of 125 refereed items. The publication rate for the past year is 32% of the manuscripts submitted during this period of time—over the five-year period of operation, 531 refereed items were published out of the 1,742 submissions, yielding a publication rate of 30.5%.

Besides the refereed material, the August 1991 issue will contain twenty-one invited papers and discussions from the 1990 winter meetings, and the December 1991 issue will contain the invited papers, discussions, addresses, and other related items from the 1991 meetings. Finally, the 1991 volume also will contain forty-seven book reviews under the excellent leadership of Dale Adams.

The Board of Associate Editors continued to provide excellent services to the *Journal*, and we also cite in an accompanying appendix table the names of those individuals who provided reviews of manuscripts during the past year. I would also like to ac-

Table 1. Response Times for Manuscripts and Reviewers, 1990–91

	Manuscripts			Reviewers		
Days	Submission One	Submission Two	Submission Three	Submission One	Submission Two	Submission Three
	(%)					
0 to 15	5	44	88	5	7	0
16 to 30	2	11	2	15	18	20
31 to 45	9	20	4	26	31	46
46 to 60	25	8	2	26	23	16
61 to 75	20	7	0	12	8	3
76 to 90	18	3	4	7	4	6
91 to 105	10	3	0	4	5	6
106 to 120	5	1	0	2	2	0
121 to 135	3	2	0	2	1	0
136 to 150	3	1	0	1	1	0
Over 150	0	0	0	0	0	3
Total	100	100	100	100	100	100
	(days)					
Average	70	33	9	51	48	48

knowledge the support provided to the editorial office by the Department of Agricultural Economics at the University of Illinois and the continued assistance of senior associate editors Phil Garcia and John Braden, editorial assistant Phyllis Blackford, and technical editor Martha Luzader. Martha Luzader soon will be retiring after fifteen years of service as technical editor of *AJAE*. Her high quality work indeed will be missed.

In closing, I would like to thank the membership and executive boards of the American Agricultural Economics Association for trusting me with the responsibility to be editor of *AJAE* for the last five years. Our goals were to continue to publish a high quality professional journal that would reflect the broad interests and responsibilities of the membership of AAEA, and to do so in as timely and efficient manner as possible. For me, the experience indeed will be a memorable one, and I have especially enjoyed becoming acquainted with many of the fine people who make up our profession.

Thank you very much.

Peter J. Barry, editor

Appendix

Reviewers, July 1990 to July 1991

Philip C. Abbott
David Abler
Dale W Adams
Darius M. Adams
Richard M. Adams
Roy D. Adams
Adesoji O. Adelaja
Mary Ahearn
Jay Akridge
Harold Alderman
Mubarik Ali
David Allee
Julian Alston
Klaus Alt
James L. Anderson
Jock Anderson
Julie Anderson
Kym Anderson
Margot Anderson
Robert A. Androkovich
John Antle
Frances Antonovitz
Pier Giorgio Ardeni
Louise Arthur
Azzeddine Azzam
Emerson Babb
Bruce Babcock
John Baffes
DeeVon Bailey
C. B. Baker
Malcolm Bale
Eldon Ball
Nicole Ballenger
Badi H. Baltagi
Randolph Barker
Andrew Barkley
Richard L. Barrows
Sandra Batie
Phillip Baumel
Bruce R. Beattie
John Beghin
Jere Behrman
Michael Belongia
Peter Berck
John Bergstrom
G. Andrew Bernat
David Bessler
Ronald Bewley
James Binkley
Leroy Blakeslee
Steven Blank
James Blaylock
Don Blayney
Nancy E. Bockstael
Michael Boehlje
William Boggess
Richard Boisvert
James T. Bonnen
Darrell Bosch
Howarth Bouis
Roy Boyd
Kevin Boyle
J. B. Braden
Jon Brandt
Boris E. Bravo-Ureta
Maury E. Bredahl
John P. Brennan
Daniel W. Bromley
Wade Brorsen
Deborah Brown
Mark Brown
Steven Buccola
David Bullock
Joseph Buongiorno
Oscar Burt
Robert O. Burton
Rueben C. Buse
Walter Butcher
Derek Byerlee
Peter H. Calkins

Appendix (Continued)

Trudy Cameron
Susan Capalbo
Oral Capps
Gerald Carlson
Hoy Carman
C. A. Carter
Michael Carter
Emery N. Castle
Julie Caswell
Margriet F. Caswell
James Chalfant
Robert G. Chambers
Jean-Paul Chavas
E. Kwan Choi
Jack Clark
Mark J. Cochran
Bonnie Colby
Robert Collender
Phil L. Colling
David R. Colman
John Connor
Richard Connor
Patrick J. Conway
Roger Conway
Stephen Cooke
Sam Cordes
Dennis Cory
Thomas Cox
Ian Coxhead
Barry Coyle
Keith Criddle
John B. Crihfield
Carlos Cuevas
Roger Dahlgran
Leon Danielson
Christina C. David
P. J. Dawson
Richard Day
David Debertin
Harry de Gorter
Alain de Janvry
Christopher Delgado
Michael Denny
S. Devadoss
Barbara Devaney
Ariel Dinar
Bruce L. Dixon
Otto Doering
Arthur J. Dommen
Jeffrey Dorfman
Paul Driscoll
James A. Duffield
Patricia A. Duffy
Ron Durst
James S. Eales
Robert Emerson
James Epperson
B. L. Erven
Don Ethridge
Robert Evenson
Paul Fackler
Marcel Fafchamps
Barry Falk
Richard Fallert
Merle Faminow
Shenggen Fan
Rolf Färe
Richard L. Farnsworth
Allen Featherstone
Gershon Feder
Martin L. Fischer
Anthony C. Fisher
Brian Fisher
Paul R. Flacco
Stanley M. Fletcher
Ray Folwell
Olan Forker
Lynn Forster
T. Randall Fortenbery
William E. Foster
Glenn Fox
Betsy Frazao
John Freebairn
A. Myrick Freeman
Ben C. French
George B. Frisvold
Edward O. Fryar
Lilyan Fulginiti
Stephen Fuller
Murray Fulton
Gene Futrell
Paul Gallagher
B. Delworth Gardner
Peter V. Garrod
C. M. Gempesaw
Joe Glauber
Ellen Goddard
E. Bruce Godfrey
Barry Goodwin
Brian Gould
Richard Grabowski
Richard Green
Orlen Grunewald
David Guilkey
Harold D. Guither
Russell Gum
Lewell Gunter
Catherine Halbrendt
Darwin C. Hall
Arne Hallam
Jerome Hammond
Steven Hanson
J. Brian Hardaker
Neil Harl
David Harrington
Robert J. Hauser
Joseph Havlicek
Yuyiro Hayami
Marvin Hayenga
Dermot Hayes
Peter Hazell
Dale Heien
Richard G. Heifner
Ralph Heimlich
Gloria Helfand
Daniel Hellerstein
Peter G. Helmberger
Glenn Helmers
M. S. Henry
Robert W. Herdt
Thomas Hertel
Julie Ann Hewitt
L. Dean Hiebert
R. James Hildreth
Lowell D. Hill
Dana Hoag
John P. Hoehn
Garth J. Holloway
Matthew Holt
James Houck
Wayne Howard
Charles W. Howe
Shih-Hsun Hsu
Chung L. Huang
Kuo Huang
Ray G. Huffaker
Wallace Huffman
Leroy J. Hushak
Robert D. Innes
Shoichi Ito
James Jacobs
Helen Jensen
Kimberly Jensen
Gale Johnson
Thomas Johnson
Timothy E. Josling
Richard Just
K. H. Kahl
E. H. Kaiser
Harry Kaiser
Toshiyuki Kako
Larry Karp
Michael Kaylen
Mary Jo Kealy
Earl Kellog
Lawrence Kenny
Robert P. King
Henry Kinnucan
Jean Kinsey
Richard M. Klemme
Darrel Kletke
James B. Kliebenstein
Catherine Kling
Keith Knapp
Tom Knight
Odin K. Knudsen
Mary K. Knudson
Ron Knutson
Ulrich Koester
William Kost
Carol S. Kramer
Randall Kramer
Yoshimi Kuroda
Eddy L. LaDue
Jeffrey LaFrance
George Ladd
David Lambert
Sylvia Lane
John S. Lapp
Bruce Larson
Douglas Larson
Bruno Larue
William Lazarus
David Lee
Hynok Lee
Jong-Ying Lee
Linda Lee
Tsoung-Chao Lee
Uma Lele
M. L. Lerohl
Raymond M. Leuthold
Erik Lichtenberg
Justin Yifu Lin
William Lin
Robert K. Lindner
Douglas Lipton
Donald J. Liu
James E. Long
John B. Loomis
Ramon Lopez
Rigoberto A. Lopez
H. Alan Love
Ernst Lutz
Carl Mabbs-Zeno
Mark Machina
Harry Mapp
Bruce Marion
Michele Marra
Michael V. Martin
Philip Martin
William E. Martin
Alex McCalla
Francis McCamley
Bruce A. McCarl
Kenneth E. McConnell
Vicki McCracken
Tom McGuckin
Anya McGuirk
Chris McIntosh
William T. McSweeny
Karl Meilke
Martin I. Meltzer
Jack Meyer
Richard L. Meyer
William Meyers
S. E. Miller

Appendix (Continued)

Thomas A. Miller
Tracy C. Miller
Mario J. Miranda
Ron Mittelhammer
James Mjelde
Joe Moffitt
Eric Monke
Michael R. Moore
Giancarlo Moschini
Charles Moss
J. Austin Murphy
Wesley N. Musser
Robert Myers
Carl Nelson
Gerald C. Nelson
David M. G. Newbery
Paul Newbold
David Newman
Richard Norgaard
George Norton
James Oehmke
Susan E. Offutt
Hayri Ōnal
Tongroj Onchan
David Orden
Tim Osborn
Daniel Otto
Don Paarlberg
Philip Paarlberg
Angelos Pagoulatos
Ray Palmquist
Quirino Paris
E. C. Pasour
George Patrick
Allen B. Paul
Scott Pearson
Anne E. Peck
Glenn Pederson
J. B. Penn
John Penson
Jeffrey M. Perloff
Richard Perrin
Gregory M. Perry
G. H. Peters
Wesley Peterson
Willis Peterson
Todd E. Petzel
Tim T. Phipps
Daniel Pick
Per Pinstrup-Andersen
Leo Polopolus
Greg Pompelli
C. Arden Pope
Rulon D. Pope
Barry M. Popkin
Anthony Prato
Paul Preckel
Warren Preston
David Price
Wayne Purcell
Daniel S. Putler
John Quiggin
Alan Randall
Vithala R. Rao
Philip Raup
Gordon C. Rausser
Martin Ravallion
Daryll Ray
Subhash C. Ray
Richard C. Ready
Michael Reed
Mitch Renkow
V. James Rhodes
James Richardson
Ed Rister
Lynn Robbins
Tanya Roberts
Lindon J. Robison
M. Henry Robison
Terry Roe
Mark W. Rosegrant
Howard Rosenberg
Mark Rosenzweig
John Rowse
Randal Rucker
C. Ford Runge
David E. Runkle
Fred Ruppel
Vernon Ruttan
Elisabeth Sadoulet
Gustavo Sain
Peter J. Saunders
Maurice Schiff
Allan A. Schmid
Peter Schmidt
Andrew Schmitz
Lee Schrader
Ted Schroeder
G. Edward Schuh
T. Paul Schultz
Bryan Schurle
Grant M. Scobie
Frank S. Scott
Eduardo Segarra
Kathleen Segerson
Ann H. Seitzinger
Richard J. Sexton
Leonard Shabman
James D. Shaffer
Ron E. Shaffer
Matthew Shane
Bruce Sherrick
J. Scott Shonkwiler
Richard Shumway
I. J. Singh
David Smallwood
Kerry Smith
Steven T. Sonka
Thomas H. Spreen
Stan Spurlock
Dale Squires
Bernard Stanton
Spiro Stefanou
Ivar Strand
John Strauss
Deborah Streeter
Daniel A. Sumner
W. Burt Sundquist
Earl Swanson
Scott M. Swinton
Steve Taff
Stefan Tangermann
Loren Tauer
Daniel Taylor
Daphne Taylor
Timothy G. Taylor
Gary Thompson
Stanley R. Thompson
Walter Thurman
C. Peter Timmer
George Tolley
William G. Tomek
L. Allen Torell
James Trapp
Francis Tuan
Steve Turner
Stephen Turnovsky
Calum Turvey
Luther Tweeten
Laurian Unnevehr
G. C. Van Kooten
Eileen O. van Ravenswaay
Harald von Witzke
Thomas I. Wahl
David Walker
Ron Ward
Peter G. Warr
Myles Watts
Robert D. Weaver
Alfons Weersink
Mike Weiss
Paul Westcott
Fred C. White
Marilyn Whitney
Norm Whittlesey
Lois Willett
Jeffrey C. Williams
Paul Wilson
William W. Wilson
Michael Wohlgenant
Chung-Ming Wong
Mike Woods
Robert A. Young
Thomas Zacharias
Hector Zapata
Kelly Zering
David Zilberman
Carl R. Zulauf

Report of *CHOICES* Editor

Issues of the magazine continue to be published quarterly. Circulation is now between 14,000 and 15,000. The number of writers in each issue has ranged from 30 to 36. Writers include people who are not members of AAEA, as well as members of AAEA. Advisory council members review submissions and advise on editorial activities. The board of the association reviews financial aspects of the magazine and makes the related financial decisions.

The association has announced a special competition focused on "Choices for the 21st Century." Winning submissions will make up the third quarter 1992 issue of *CHOICES*, which will be available at the August 1992 meeting of the association. Selection criteria and other contest information are included in the second quarter 1991 issue of *CHOICES*.

August 1 marks the completion of the second year for the Kellogg grant to the American Agricultural Economics Association and the American Agricultural Editors' Association. During the second year of

the Kellogg Project, press releases were prepared for each issue of *CHOICES* and press conferences were held in connection with the release of three of the issues of *CHOICES*. A press conference was scheduled for the release of the other issue. However, it was cancelled because of a travel conflict by the anticipated presenter. The American Agricultural Editors' Association took the lead in planning and holding two press backgrounders. One of these was in connection with their October 1990 annual meeting in Kansas City, the other was in June 1991 in Washington, D.C.

Activities during the coming twelve months will include press releases and conferences timed to coincide with the publication of the quarterly issues of *CHOICES*. In addition, a press backgrounder will be held in conjunction with the annual meeting of the American Agricultural Editors' Association in October 1991 and another in the spring of 1992. Discussions are underway to utilize radio outlets during the coming year and to make a special effort to work with the urban media.

Lyle Schertz, editor

Report of the *Newsletter* Editor

For the past several years, revenues (all from employment ads) and expenses have remained fairly stable, including for the six most recent issues:

Income Statement
(May/June 1990–March/April 1991)

		Annual	Issue	Copy
Revenue	=	$21,500	$3,583	$0.71
Expenses	=	30,815	5,135	1.02
Net	=	−9,315	−1,552	−0.31

The $9,315 deficit required a subsidy from general AAEA funds of approximately $1.87 per member per year.

I know of no problems or complaints with the *Newsletter*. Things work smoothly between the AAEA Business Office and me. Though space gets tight and time gets hectic, we have managed to publish and mail each issue during the first week of the first month. God bless Ms. Fax. Please feel free to make comments and suggestions at any time. Thank you.

Mike Ellerbrock, editor

Report of the AAEA Awards Committee

This year a total of 148 nominations plus all articles published during 1990 in the *AJAE* were evaluated by the nine awards subcommittees. The number submitted to each subcommittee were: Master's Thesis, 40; Ph.D Thesis, 29; Undergraduate Teaching—Under 10 Years, 7; Ten or more Years, 10; Extension Program—Individual, 2; Group, 5; Policy Contribution, 7; Communication, 19; Research Discovery, 16; Journal Article, number of articles in volume 72; and Enduring Quality, 13. Sixteen were selected for awards and nine were designated for honorable mention. A list of the award-winning entries is attached.

The submissions received thorough evaluation by subsets of the ninety-one committee members. The willingness of large numbers of the association's members to serve on these evaluative subcommittees and to devote the time required to seriously examine various submissions is necessary for this process to be useful. It says a great deal about the professional atmosphere of this association that nearly everyone asked to participate on the Awards Committee has done so willingly and effectively. The members who chaired the individual subcomittees deserve particular appreciation for the considerable time, effort, and leadership devoted to this process.

Each of the issues raised last year by outgoing general chair, Steve Sonka, elicited comment and in some cases recommendations from members of this year's Awards Committee. Recommendations were made to the board aimed at (*a*) increasing numbers of submissions in several categories by simplifying nomination procedures, (*b*) assuring an adequate number of nominations prior to making an award, (*c*) making AAEA membership a condition for receiving an award, and (*d*) updating and distributing information about the awards program. The board approved the following simplified nomination procedures for the Undergraduate Teaching, Extension Program, and Policy Contribution award categories:

"The letter of nomination (maximum of 3 single-spaced pages) will be the centerpiece for evaluation. It should contain a concise statement which summarizes the reasons the nomination is worthy of award. The letter of nomination should focus on hard evidence that the nomination meets the criteria by which entrants are judged. Supporting materials are limited to 3 items (videos, publications, etc.). They should be the nominee's best examples of quality pertaining to the award category. No other material may be submitted."

A standardized nomination procedure for the Enduring Quality category was also approved:

"Nominations should be accompanied by a short statement (maximum of 3 single-spaced pages) documenting the publication's contribution to the profession. Other than copies of the publication, no other material may be submitted."

In addition, the bylaws were amended in the business meeting to set an upper limit on the number of awards that can be given annually in each category.

It has been an honor to serve as general chair of the Awards Committee this year. The cooperation and support of President Johnston, Lona Christoffers, and all the Awards Committee members has been terrific.

Annual Awards

Distinguished Undergraduate Teaching

Less than ten years' experience. **Carl R. Zulauf**, Ohio State University.

More than ten years' experience. **Wayne D. Purcell**, Virginia Polytechnic Institute and State University.

Distinguished Extension Program

Individual. **G. Art Barnaby**, Kansas State University, "Multiple Peril Crop Insurance."
Group. "National Rural Policy Project." Texas A&M University, **Ronald D. Knutson, Dennis U. Fisher, and Sue H. Jones**.

Distinguished Policy Contribution

Jon A. Brandt, Abner W. Womack, Kenneth Bailey, Gary Adams, and D. Scott Brown, University of Missouri, and **Stanley R. Johnson, William H. Meyers, Pat Westhoff, Brian Buhr, Michael Helmar, and Deborah Stevens,** Iowa State University (all with the Food and Agricultural Policy Research Institute) for their quantitative analysis of agricultural and trade policies and their timely policy assessments.

Publication of Enduring Quality

Yair Mundlak, University of Chicago and International Food Policy Research Institute, "On the Pooling of Time-Series and Cross-Section Data." *Econometrica* 46(1978):69–85.

Outstanding Journal Article

Mitch Renkow, Rockefeller Foundation and International Maize and Wheat Improvement Center, "Household Inventories and Marketed Surplus in Semisubsistence Agriculture." *Amer. J. Agr. Econ.* 72(1990):664–75.

Quality of Communication

Kristen Allen, ed. *Agricultural Policies in a New Decade,* Resources for the Future and Food and Agriculture Committee, National Planning Association, Washington DC: Resources for the Future, 1990. Additional authors included **George E. Rossmiller, Michael F. Brown, Joseph V. Kennedy, Jon Visser, Patrick O'Brien, William H. Meyers, Andrew S. Morton, Robert L. Thompson, Tim T. Phipps, Daniel A. Sumner, Thomas W. Hertel, James P. Houck, Katherine Reichelderfer, David Blandford, Harry de Gorter, Praveen Dixit, Stephen Magiera, Alan Barkema, Mark Drabenstott, Luther Tweeten, John A. Schnittker, and Lynn Daft**.
Agricultural and Trade Analysis Division, Economic Research Service for USDA briefing booklets:
William T. Coyle and William J. Hudson, "The Basic Mechanisms of Japanese Farm Policy," Feb. 1990; **Walter H. Gardiner and William J. Hudson**, "The Basic Mechanisms of European Community (EC) Farm Policy," Aug. 1990; **Stephen L. Magiera, Michael T. Herlihy, William J. Hudson, and Jonathan Harsch**, "Multilateral Trade Reform: What the GATT Negotiations Mean to U.S. Agriculture (Long and Short Forms)," Aug. 1990.

Quality of Research Discovery

Lawrence Haddad, International Food Policy Research Institute, and **Ravi Kanbur**, University of Warwick. "How Serious Is the Neglect of Intra-Household Inequality?" *Econ. J.* 100(1990):866–81.
Honorable Mention. **Jean-Paul Chavas and Thomas L. Cox**, University of Wisconsin. "A Non-Parametric Analysis of Productivity: The Case of U.S. and Japanese Manufacturing." *Amer. Econ. Rev.* 80 (1990):450–64.
Richard E. Just, University of Maryland, **David Zilberman**, University of California, Berkeley, **Eithan Hochman**, Ben Gurion University of the Negev, and **Ziv Bar-Shira**, University of California, Berkeley. "Input Allocation in Multicrop Systems." *Amer. J. Agr. Econ.* 72(1990):200–209.
Giancarlo Moschini, Iowa State University. "Nonparametric and Semiparametric Estimation: An Analysis of Multiproduct Returns to Scale." *Amer. J. Agr. Econ.* 72(1990):589–96.

Outstanding Ph.D. Theses

Kimberly S. Rollins. "Agriculture and Wildlife: from Principal-Agent to a Wisconsin Economic Policy." University of Wisconsin (Richard C. Bishop, advisor).
Monte L. Vandeveer. "Demand for Crop Insurance and Contract Design: A Case Study for Corn in Indiana." Purdue University (Edna T. Loehman, advisor).
Naomi Zeitouni. "Efficient Management of Groundwater Quality: An Evaluation of Spatially Differentiated Policies." University of Rhode Island (James Opaluch, advisor).
Honorable Mention. **Nir Efraim Becker**. "Dynamic Supply from a Common Property Resource: Water Division from the Great Lakes." University of Minnesota (K. William Easter, advisor).
Martin Benirschka. "Farmland Value Changes, Grain Storage and Livestock Production in a Geographically Dispersed Market." Purdue University (James K. Binkley, advisor).
Douglas D. Parker. "The Economics of Marketing Agricultural Product Quality." University of California, Berkeley (David Zilberman, advisor).

Outstanding Master's Theses

Eric D. Ebel. "Analysis of Economics of Pseudorabies Disease in Swine Using a Stochastic Simula-

tion Model of a Farrow-to-Finish Operation." University of Illinois (Robert H. Hornbaker, advisor).

David Sauder. "Simulation of the Tripartite Stabilization Program for Hogs in Saskatchewan Given Rational Expectations." University of Saskatchewan (John D. Spriggs, advisor).

Zhi Wang. "The Effects of Rationing on Consumption Behavior of Chinese Urban Households During 1981–87." Ohio State University (Wen S. Chern, advisor).

Honorable Mention. **Juan Andres Espinosa**. "Hedonic Price Estimation for Kansas Wheat Characteristics: A Pooled Cross-Sectional Time-Series Analysis." Kansas State University (Barry K. Goodwin, advisor).

Katherine Griffith. "Environmental and Economic Trade-offs in the Costa Rican Dairy Industry: A Linear Programming Approach." University of Wisconsin (Lydia Zepeda, advisor).

Andres Guarderas. "Food Demand and Food Policy in Ecuador: Analysis of the Distributional and Nutritional Impacts of the Wheat Import Subsidy." Cornell University (David R. Lee, advisor).

C. Richard Shumway, chairperson

Report of the AAEA Foundation, 1990–91

The AAEA Foundation Governing Board met 4 August 1991 at Kansas State University. Principal items of information and action were as follows.

Contributions totalled $28,897 in the year ending 31 July 1991; assets are now approximately $140,000.

The Gerald W. Dean Appreciation Club was chartered ($10,000) at the Kansas State AAEA meeting; the John D. Block Appreciation Club attained the $20,000 endowment status level, now joining the Earl O. Heady Club as being chartered in perpetuity.

Principal program activities in 1990–91 included cosponsorship of attendance of twelve East European and Soviet agricultural economists at the Kansas State meeting; travel assistance to twenty-two undergraduates and one minority professional to attend the Kansas State meeting; travel assistance to two minority professionals to attend the IAAE meeting in Japan; and shipment of *Journals* to the University of La Molina, Peru.

The board approved initiation of an expanded fund development program for 1991–92 including: a deferred-giving campaign, encouragement of additional Appreciation Clubs, sale of ads in the special 1992 essay edition of *CHOICES*, and an accelerated member- and corporate-giving campaign with assistance of Foundation Associates.

Newly elected board members (3 years) are Susan Offutt, Office of Management and Budget, and Ed Rossmiller, Resources for the Future, replacing Lawrence Boger and Kenneth R. Farrell. AAEA executive representatives in 1991–92 are Warren Johnston (1 year), Ralph Christy (2 years), and Vernon Eidman (1 year). Johnston and Christy replace Sandra Batie and Walter Armbruster, respectively.

Officers of the Governing Board for 1991–92 are John E. Lee, Jr., president; Gene L. Swackhamer, vice-president, finance; W. Burt Sundquist, vice-president, programs; and Raymond R. Beneke, secretary-treasurer.

Kenneth R. Farrell, president
AAEA Foundation Governing Board

Report of the Committee on Women in Agricultural Economics

The CWAE chair appointed eleven subcommittees and two liaisons to carry out CWAE activities this year. These were published in the fall issue of the *CWAE Newsletter*.

Joy Harwood edited the summer/fall 1990 issue of the *CWAE Newsletter*. Nancy Morgan edited the winter 1990 and spring 1991 issues. Linda Calvin, Stephanie Mercier, and Claudia Parliament assisted as members of the Newsletter Committee. The newsletter had 240 subscribers this year, a 41% increase over last year. Part of this increase is certainly because of the AAEA Board's decision to include the *CWAE Newsletter* on the AAEA omnibus subscription form. Additional copies are also distributed free to female graduate students.

The Scholarship Subcommittee (Maureen Kilkenny, chair, Sermin Hardesty, Jean Kinsey, Edna Loehman, Carole Nuckton, and Tanya Roberts) convened a panel of experts in December 1990 in Washington, D.C., to determine how other people set up their scholarship funds and how CWAE might complement existing programs. Participants included the director of the NSF economics program, the vice-chancellor for research at the University of Missouri, a representative from Educational Testing Services' Panel on the Study of Graduate Student Support and the Ph.D. Labor Supply, the director of the Fellowship Program of the U.S. Institute of Peace, director for fellowships at the AAUW, a senior fellow from RFF, and two CWAE members (Maureen Kilkenny and Tanya Roberts). The results will be reported at the summer 1991 CWAE business meeting in Manhattan, Kansas. The Scholarship Committee also set up a calendar of 300-plus grant, internship, and fellowship opportunities so that notices could be inserted into the *CWAE Newsletter* six months before and again three months before applications are due.

The Graduate Student Subcommittee (Hui-Shung Chang, chair, Mary Marchant, Lydia Zepeda, and Amy Purvis) collected information last year on the numbers of women agricultural economics faculty and graduate students. The results will be presented at a poster session at the 1991 AAEA annual meetings. CWAE has been concerned about what it might do to help female agricultural economics graduate students. The Graduate Student Subcommittee this year

surveyed female graduate students to identify what assistance such students most need to successfully complete their degrees, whether financial support to stay in school, mentoring support from advisors/faculty or senior faculty, computer/office space/xerox support, or whatever. The Research Subcommittee (Laurian Unnevehr, chair, Hui-Shung Chang, Sarahelen Thompson, and Jill Findeis) has worked closely with the Graduate Student Subcommittee on this project, and the two committees plan to publish initial results of this survey in the summer/fall 1991 *CWAE Newsletter*. The Research Subcommittee is also organizing a symposium, "Leadership Skills Opportunities and Experiences," at the Manhattan meetings.

The Professional Activities Subcommittee (Christina Gladwin, chair, Jean Due, June Grabemeyer, Eileen Muiragui, Laurian Unnevehr, and Ann Vandeman) coordinated a CWAE workshop on sexual harassment at the 1990 AAEA meetings. In order to make this information available to more AAEA members, the workshop was videotaped with the generous assistance of the Resources and Technology Division of ERS. Two copies of this tape are now available for loan to AAEA members. They can be obtained by contacting Ann Vandeman at ERS (202-219-0433).

The Arrangements Subcommittee (Penny Diebel, chair, and Lisa Abeles-Allison) has arranged a luncheon, a business meeting, and a reception at the 1991 AAEA annual meetings. Jean Kinsey will speak at the luncheon. Nicole Balinger of the Council of Economic Advisors will speak at the reception.

The Elections Subcommittee solicited nominations for the 1991–92 CWAE vice-chair and two board members to serve two-year terms. They developed a ballot with two nominations for vice-chair and four nominations for board members which was mailed to all women AAEA members and to subscribers of the *CWAE Newsletter*. Vicki McCracken was elected vice-chair. Shida Henneberry and Laurian Unnevehr were elected board members. Continuing board members are Joy Harwood, chair; Deb Brown, past-chair; Julie Caswell; and Bonnie Colby.

The Archives Subcommittee (Ardelle Lundeen, chair, and Sylvia Lane) has received material from the 1989–90 officers and committees and is storing it.

Joyce Hall, CWAE liaison to CSWEP, has worked to establish closer ties with our counterpart organization.

The Planning Subcommittee (Julie Caswell, chair, Mary Ahearn, Fran Antonovitz, Carol Kramer, Linda Lee, and Colletta Moser) has been discussing research CWAE might do on whether there is a glass ceiling for women in agricultural economics. They also are considering whether CWAE should present a career development program at the annual meetings on "How to Do Consulting."

The Employment Subcommittee (Linda Calvin, chair, Kristin Allen, Cheryl Donley, Elizabeth Dunn, Jill Findeis, Sermin Hardesty, Lori Lynch, and Emily McClain) has continued to canvass employers to advertise in the *CWAE Newsletter*. They are also going to try to obtain information on summer internships this fall, so that they can be advertised in the winter issue of the newsletter.

CWAE lost a good friend when Gene Futrell, AAEA board representative to CWAE, died. He will be missed.

Deborah J. Brown, CWAE chairperson

Minutes

Minutes of the AAEA Executive Board Meeting, Columbus, Ohio, 30 November–1 December 1990.

Present: Voting Members:
Armbruster, Batie, Beattie, Deaton, Eidman, Futrell, Johnston, Libby, Reichelderfer

Members ex-officio:
Barry, Beneke, Schertz

Guests:
Carsrud, Christoffers

The meeting of the Executive Board of the American Agricultural Economics Association convened at 8:30 A.M. in the Marion Room of the Hyatt Regency Columbus, Friday, 30 November 1990. President Warren E. Johnston opened the meeting with announcements and a review of the agenda.

1. The minutes of the executive board meeting held in Vancouver, British Columbia, Canada, 3–4 August 1990 were approved as amended.

2. Johnston announced that the executive board is to meet in San Antonio, Texas, 25–26 January 1991, with an 8:00 A.M. continental breakfast.

3. Vernon Eidman presented two proposals received by him in response to the "Call for Editorship" of volumes 74–76, 1992–1994, of the *American Journal of Agricultural Economics*. MOTION: After a lengthy discussion by the board, Bruce Beattie moved to accept the proposal by Oregon State University. Gene Futrell seconded. Motion carried. The proposed coeditors, Richard Adams and Steve Buccola, will be contacted regarding the list of associate editors they had prepared. The board requested that the editors make an effort to achieve greater diversity on the board of associate editors than is reflected in the panel currently proposed.

4. Beattie led a discussion of Invited Paper Sessions proposals for the 1991 meeting at Kansas State. The topics agreed upon and the board member who accepted the responsibility to interact with the appropriate organizer for each session are as follows:

Commercial Agriculture: production, marketing, price analysis, finance, agribusiness.

Session 1. Michael Hudson—"Agribusiness Competitiveness in the 1990s" (proposal originated with the Industry Committee, Eidman)

Session 2. Allen M. Featherstone—"Financing Agriculture Under Changing Environment Regulations: Academic, Legal, and Practical Issues" (NC-161, Libby)

Ag policy, macrolinkages, and value added.

Session 3. "Improving Macroeconomic Policy Linkages in Agricultural Research and Extension" (originated in the Extension Committee, Futrell)

International trade and development.

Session 4. Christina Gladwin—"The Gendered Impacts of Structural Adjustment Programs in Africa" (proposed jointly by the International Committee and CWAE, Armbruster)

Natural resources economics.

Session 5. Chuck Howe—"Evaluating Programs That Save Lives" (proposed by AERE, Batie)

Theory and methodology.

Session 6. Walter Thurman—"Developments in Applied Welfare Economics," Beattie)

Other.

Session 7. Magid Dagher—"The Agricultural Economics Profession and Limited Resource Farmers" (Committee on Status of Blacks in Agricultural Economics, Deaton)

Session 8. Kim Reda-Wilson—"Why and How AAEA Should Be Involved with Youth Economic Education" (Economic Education Committee, Johnston).

MOTION: It was moved by Eidman and seconded by Walter Armbruster to accept the set of Invited Papers Sessions as discussed. Motion carried.

MOTION: Beattie moved that a letter be sent encouraging persons in selected cases to resubmit the proposals as organized symposia. Armbruster seconded. Motion carried. Paper presenters, speakers, and titles are to be in place and reported at the January 25th board meeting.

5. Larry Libby led the board through the AAEA Fellows selection process and reviewed the guidance provided in the constitution and bylaws on criteria for selection and the procedures followed in past years. After lengthy review of the list of nominees and several rounds of sequential balloting, nine names emerged to be forwarded to the Fellows Selection Committee.

The meeting adjourned at 5:00 P.M. to reconvene at 8:00 A.M. Saturday.

6. Johnston announced that Rueben Buse of Wisconsin was now our liaison to the National Bureau of Economic Research. He will serve for a three-year term. It was reported that the bureau will pay for travel costs involved for representatives to attend two meetings per year.

7. Johnston reported on the president's visit to Washington, D.C., in October, stating that they were able to visit with agency heads, assistant secretaries, and a number of major supporters of *CHOICES* Magazine.

8. Johnston had been in contact with Arne Larsen, president of the European Association of Agri-

cultural Economists, and the two have mutually agreed to greater cooperation between the AAEA and EAAE beginning with the exchange of newsletters in order to inform members of each group concerning events of interest taking place in both associations.

9. Johnston reminded board members of their responsibility as board representative to the various committees and asked each to contact the committee chair and to become involved with the activities of the committee.

10. The president announced that there would be no AAEA board meeting in conjunction with the ASSA meeting to be held 27–30 December 1990, in Washington, DC. However, there will be an AAEA-sponsored reception held Friday, 28 December at the Washington Hilton at 5:30 P.M.

11. Johnston reported that he had thanked the Institute of Food Technologists for the invitation to be listed as endorsing their workshop but had informed them that the board had elected not to participate at this time.

12. The matter of the World Food Prize was discussed. It was agreed that a committee should be formed to develop criteria that would help in preparing an appropriate packet of materials. The matter was tabled until the January meeting.

13. A discussion of the present status of the Survey of Literature Review took place with the board concluding that a report at the January meeting on the progress toward publication of this material would be appropriate.

14. Johnston referred to a letter he had received from Julio Hernandez-Estrada, Director of the Mexican Agricultural Economist Association, whereby he indicated their willingness to work jointly to foster a closer relationship between the two associations. The AAEA board expressed interest in having several joint activities at the 1994 AAEA annual meeting. The need to identify a member of our association to function as liaison and to advise our association on how best to promote interest in the Mexican arrangement was discussed. Johnston and Beattie will follow up with a report either in January or August.

15. A proposal for a preconference workshop from the Social Science Agricultural Agenda Project (SSAAP) was discussed. The preconference will be held at a location in Kansas City, Missouri, prior to the annual meeting in Manhattan. The tentative dates of the preconference are 1–4 August 1991. There will be no direct cost to the association for this preconference, but the organizers will promote the activity with our preregistration materials.

MOTION: Sandra Batie moved that the AAEA agree to cosponsor this preconference. Armbruster seconded. Motion carried.

16. Armbruster reported on a three-part proposal for increasing master's degree students and industry participation in the AAEA Employment Service and other AAEA activities, submitted by the Employment Services Committee:

(*a*) One-page monthly *Job Openings for Agricultural Economists* (*JOAE*). Members of the board agreed with Armbruster that this is an interesting concept, but the demand for this service is not clear at this point. The board suggested further study and that an effort be made to appraise the demand for this service.

(*b*) Establish an Outstanding Master's Paper Award (OMPA). This award would be in addition to the existing Outstanding Master's Thesis Award. No resolution was made of the proposal.

(*c*) An information session focusing on the recruitment process be arranged at the AAEA meetings. The session would target the master's nonacademic candidates as well as potential employers from industry. The committee also proposed that as part of the program employers could give generic talks on how to be a good employee. The board felt this session would be useful to undergraduates as well. The board postponed any further action until the January meeting when it will consider forming a task force to explore how best to meet the needs of M.S. graduates. Brady Deaton will bring suggestions to the board meeting in January.

17. A letter from George Patrick, chair, AAEA Extension Committee, informed the board that the Extension Committee recommends continuing the Commodity Outlook Session as a regular part of the summer meetings and also supports the continuation of the extension luncheon. The committee recommends further that a Public Policy Outlook Session be implemented on a pilot basis at the 1991 summer meeting.

MOTION: Armbruster moved we accept these recommendations as presented. Beattie seconded. Motion carried.

18. A proposal for the Frederick V. Waugh Memorial Lecture Series was discussed. Board members suggested several revisions.

MOTION: Beattie moved to accept the proposal as revised, with the lecture scheduled as a plenary session at the AAEA annual meeting to be published in the proceedings issue of the *American Journal of Agricultural Economics*. Katherine Reichelderfer seconded. Motion carried.

19. The board met informally with the Student Section officers and advisors after which SS-AAEA President Jeana Brandt informed board members about SS-AAEA activities. She reported upcoming changes to the SS *Journal*, *Newsletter* and *Handbook/Directory*, and indicated that the student section was exploring ways to integrate activities with graduate students. Members of the board agreed to poll their graduate students to ascertain the latter's wishes on being included in the Student Section and report their findings in January.

20. The following SS-AAEA constitutional changes were presented: (changes appear in bold print)

ARTICLE VII.

Section 5. (not presently in the constitution) **The Associate Advisors of the SS-AAEA shall serve as individual advisors for SS-AAEA officers and serve**

as judges and officials for student contests. Associate advisors will be from the institution of an SS-AAEA officer to work with and support the officer's activities and consult on the duties listed in Section 4. Each officer will submit a name from their institution to serve as an associate advisor for approval from the advisors.

ARTICLE IX.

Section 3. The voting procedure to be followed at the meetings of the SS-AAEA shall be as follows: each chartered chapter is allowed up to two voting delegates with each delegate allotted one vote. There will be no proxies and all voting delegates must be present at the roll call **to determine who voting delegates are.**

ARTICLE XII.

Section 1. Amendments to this constitution may be made by a 2/3 **secret ballot** vote of the voting delegates present **or by mail ballot of delegates present at summer meeting,** followed by transmittal to the Executive Board of the AAEA for approval. The addition of bylaws and the revision thereof shall be accomplished in a like manner.

ARTICLE III.

Section 2. The charter fee, **set by the Executive Committee of the SS-AAEA,** shall be due every five years with all charters up for renewal on years divisible by five (5) e.g., 1985, 1990.

ARTICLE V.

Section 1. The annual dues for chapters of SS-AAEA shall be **set by the Executive Committee of the SS-AAEA and** payable to the SS-AAEA and shall be for the current calendar year.

ARTICLE V.

Section 3. **Dues for the individual for the calendar year shall be less than the annual chapter dues amount and set by the Executive Committee of the SS-AAEA.**

ARTICLE VI.

Section 1. The officers of the SS-AAEA shall be: President, Vice-President for each region, Secretary-Treasurer, **Newsletter Editor, and Journal Editor.** All officers must meet the membership requirements of Article IV, Section 1 or Section 2. The term of office shall be for one year and all officers shall be elected at the SS-AAEA annual meeting by **either secret ballot with a simple majority or by acclamation** of the voting delegates present and will take office at the end of the annual meeting. **These officers shall comprise the Executive Committee of the SS-AAEA.**

ARTICLE VI.

Section 4.D. (not presently in the constitution) D. **The Newsletter Editor Shall:**

1. **Keep the chapters informed at all times of the activities of the Executive Committee and the SS-AAEA.**
2. **Report to all chapters the planned activities to be presented at the summer meetings.**
3. **Maintain a current year file thereof which shall be turned over to the Newsletter Editor-elect upon expiration of term of office. All years prior shall be maintained at the business office.**
4. **Collect news from chartered chapters for dissemination to all member chapters.**
5. **Inform other national officers at all times of the Newsletter Editor's activities concerning the SS-AAEA.**
6. **Publish a quarterly newslettter for local chapters and members as described under Article IV, Section 2.**

E. The Journal Editor Shall:

1. **Provide the publication of the SS-AAEA Journal as directed by the Executive Committee.**
2. **Inform other national officers at all times of the Journal Editor's activities concerning the SS-AAEA.**
3. **Maintain and update the historical record of the SS-AAEA.**
4. **Turn over current year journals and the SS-AAEA history to the Journal Editor-elect upon expiration of term of office. Turn in all past available files to the SS-AAEA office.**
5. **Coordinate updating the office handbooks.**

MOTION: Beattie moved we accept these revisions to the Student Section bylaws. Libby seconded. Motion carried.

21. The board's attention was directed to a letter by E. Bruce Godfrey regarding a survey of the membership he would like to conduct directed at discovering why some members do not renew their membership. He also requested help from the AAEA Business Office. The board approved his proceeding with this project with the results to be available at the 1991 summer meeting.

22. A packet of material relating to a proposal to create a National Institutes of the Environment was discussed. Johnston will acknowledge receipt of the materials. Reichelderfer will monitor the activity and return with a report in January.

23. Board members were then asked to consider the report of the Professional Activities Committee submitted by Paul Barkley, relating to a possible learning workshop. Board members indicated preference for the topic "The New Political Economy." It was decided to schedule the workshop tentatively on Wednesday from 10:00–12:00 A.M. and from 1:30–3:30 P.M. The board accepted the recommendation from the committee that, depending upon the success of the second learning workshop, the concept shall become a permanent part of the annual meeting, and in that event a standing committee shall be formed to take over the planning and execution of future workshops. The Professional Activities Committee will recommend operating procedures in the event the learning workshop becomes a permanent feature. The

PAC will shortly have fliers ready for printing and distribution to individuals selected to give papers, organize symposia, or prepare posters for the annual meeting.

24. John E. Lee, Jr., ERS USDA, inquired via a letter, if the AAEA would consider being a cosponsor for part of a consortium to cosponsor the 1994 IAAE meeting if it were held in the United States.

MOTION: Armbruster moved that the association cosponsor the International Association of Agricultural Economists meeting in 1994 provided that we not assume any financial responsibilities associated with the meeting. Eidman seconded. Motion carried. The board members indicated they were enthusiastic about the prospect of having the IAAE meetings in the U.S.A.

25. Charlene Carsrud presented material relating to the 1991 meeting at Kansas State University. A handout from Marc Johnson, indicating a preliminary budget, was distributed.

MOTION: Batie moved to raise the registration fee for the annual meeting by $10.00 to $80.00 for professionals, with proportional raises for other categories of participants. Reichelderfer seconded. Motion carried.

Carsrud reported that a premeeting tour of Baltimore, Maryland, was being scheduled for April 1991. The latter meeting will be held jointly with the NAREA as well as the Soil Conservation Society.

The 1993 meeting site is tentatively scheduled for Orlando, Florida. A definite decision will be made at the January meeting of the board. Libby is to visit the site in Orlando and bring the board up to date on the progress being made in the construction of the facilities we plan to use. No further steps will be taken regarding plans for the 1995 and 1996 meetings until the January meeting. The board was reminded to scrutinize the Broder report prior to the January meeting and to give special attention to comments on meeting sites and arrangements.

26. A report from an ad hoc committee of agricultural economics department chairs was discussed. This report centered on a proposed workshop for department heads focusing on problems with which they must deal. Tentative dates for such a workshop are 6–9 October 1991.

MOTION: Batie moved that the board endorse the proposed department chairs workshop for one year and invite the planning group to use the facilities of the AAEA Business Office as necessary. Eidman seconded. Motion carried.

27. The Adaptive Planning Committee report was discussed briefly. It was decided to ask the committee to create a list of interest groups and organizations that might logically interface with the association and determine how best to approach such groups. Each of the board members were asked to ponder the problems that need to be addressed at the January meeting as the board moves to implement the recommendations of the Adaptive Planning Committee.

28. Lyle Schertz, editor of *CHOICES* magazine reported for the assistant to the editor, Marie Lee, in her absence. The latter presently is concentrating on subscription promotion as well as learning the magazine's publication process. Schertz indicated that so far the arrangement has been successful.

Schertz also presented two contract changes relating to the preparation and printing of *CHOICES*. FEA Laser, Inc. is proposing a 10% increase for 1991 over the rate that has applied during the past three years, i.e., an increase from $90 to $99 per magazine page. United Litho proposes an increase of 3.2% in their charges. Paper costs are priced at market rates.

MOTION: Armbruster moved to accept these contract changes. Beattie seconded. Motion carried.

Schertz reported in several additional *CHOICES* issues:

(*a*) He proposed an association-sponsored essay contest to be announced in the spring of 1991, with winning manuscripts to be published in the 3rd issue of 1992. Schertz will approach the Foundation Governing Board to offer exclusive fund-raising rights to the foundation for the contest issue through selling advertising.

(*b*) Copyright of *CHOICES* content: The editor proposed to the board we state in the magazine that the contents can be reproduced without approval but with credit to *CHOICES*. Schertz is to investigate this further and report at the January meeting in San Antonio.

(*c*) Batie is to investigate the wording in the bylaws, Article XV, Section 3, wherein "Members of the Editorial Advisory Board shall be appointed by the President-Elect upon the recommendation of the Editor of *CHOICES*" and report back at the January meeting.

(*d*) *CHOICES* on CD-ROM: the editor continues to favor having agricultural economics literature on CD-ROM. Johnston is to ask the University of California, Davis member of AERO to evaluate CD-ROM technology with respect to AAEA publications and report back in August.

(*e*) According to the terms of the "Memorandum of Understanding," the adjustment of compensation for salary for the *CHOICES* editor beginning calendar year 1991 will be $45,835.

(*f*) A review of the financial reports for *CHOICES* magazine indicated no changes are necessary at this time in the 1991 budget.

(*g*) A proposal entitled "Economics of Agriculture for High School Students," sponsored jointly by AAEA and the Joint Council of Economic Education (JCEE) was discussed. This proposal will be given further review in January when Batie will provide a follow up report on this activity.

29. The matter of interest earned by monies on hand relating to the Kellogg Project was once again discussed.

MOTION: Batie moved that the interest earned by Kellogg Project balances will be used on activities compatible with the objectives of the project (but not previously budgeted) as proposed by project leaders

and approved by the presidents' of the associations. Libby seconded. Motion carried.

30. The matter of developing a policy on financial arrangements with AAEA committees and interest groups was tabled until the January meeting.

31. The issues that were to be brought to the board's attention from the recent meeting of the Foundation Governing Board were tabled until the January meeting.

32. The discussion of the AAEA Fellows Activity Committee (ad hoc) report was tabled until the January meeting.

33. Walter Armbruster reported as chair of the Finance Committee concerning changes that are being made in the format in which financial data are reported to the board and the membership of the association. The Finance Committee suggested the following adjustments:

(*a*) The format as recommended by the Financial Committee at the 1990 summer board meeting be followed in reporting financial results.

(*b*) A separate financial account be prepared for (*i*) *CHOICES*, (*ii*) the *American Journal of Agricultural Economics*, (*iii*) the *AAEA Newsletter*, (*iv*) the business office, (*v*) the employment service, and (*vi*) the foundation.

(*c*) The bottom line of each component be reported in the consolidated financial account.

(*d*) The auditor be requested to prepare his audit report so that it is consistent with the accounting format being followed by the business office.

(*e*) Budgets be prepared and presented at the summer board meeting which project expected monies and expenses for the next two calendar years instead of the next calendar year only as is now the practice.

(*f*) In making projections, 3% of the value of the portfolio on the previous July 1 be used in projecting estimated gains from sale of securities.

34. Johnston announced the appointment of Jeff Dorfman and Michael Wetzstein of the University of Georgia as cochairs for the Selected Paper Sessions competition. A letter from Robert Shulstad, head of the Department of Agricultural Economics at the University of Georgia was discussed wherein he asked the board to consider reimbursement of the out-of-pocket expenses associated with this effort.

MOTION: Beattie moved that the association provide partial compensation to the department of up to $1,000 for the selected paper project to help defray out of pocket costs. Futrell seconded. Motion carried.

35. The association's affiliation with the Consortium of Social Science Associations (COSSA) was discussed. The board pondered whether the dues the Association pays COSSA seem too high for the benefits received. Further discussion will take place in January.

36. The annual report for the Council of Professional Associations on Federal Statistics (COPAFS) was discussed. The board agreed that this activity is effective and it is appropriate that the association remain supportive.

37. Peter Barry provided his editor's report to the board. The *Journal* operations continue to function smoothly and the 1991 volumes are on schedule. Barry reported that the problem of timely mailing of the *Journals* seem to have abated since the change to a different publishing company took place.

38. A proposal from the AAEA China Committee was reviewed. This group is proposing a conference for 17–21 August 1992, in Beijing, China. At this point, the committee is not seeking any funding from the board but has requested the board's approval for the AAEA China Committee to cosponsor the conference.

MOTION: Batie moved that the AAEA agree to cosponsor the China Conference as proposed by the China Committee. Armbruster seconded. Motion carried. The board urged that the China Committee keep the board representative, and through him the executive board, well informed of the progress being made in planning the conference.

39. Johnston reminded the group that the San Antonio meeting in January would be considered a site visit; therefore, board members' lodging as well as transportation will be reimbursed.

40. Beneke distributed a proposal for a Workshop for the Enhancement of Professional Interaction among Agricultural Economists in the Emerging Democracies. This proposal seeks to reach out to professional agricultural economists in Eastern Europe. The proposed project would encourage the latter to participate in the annual meeting at Kansas State University. Beneke encouraged board members to read his proposal and to prepared to continue the discussion at the January meeting.

After brief announcements the meeting was adjourned at 6:25 P.M.

Respectfully submitted,

Raymond R. Beneke
Secretary-Treasurer

Minutes of the AAEA Executive Board Meeting, San Antonio, Texas, 25–26 January 1991

Present: Voting Members:
Armbruster, Batie, Beattie, Deaton, Eidman, Johnston, Libby, Reichelderfer

Members ex-officio:
Adams, Barry, Beneke, Buccola, Ellerbrock, Schertz

Guests:
Carsrud, Christoffers

Absent:
Futrell

The meeting of the Executive Board of the American Agriculture Economics Association was convened at

9:00 A.M. in the Frio Room of the Hyatt Regency San Antonio, Texas, Friday, 25 January 1991 by President Warren E. Johnston, who opened the meeting with announcements and a review of the agenda.

1. The minutes of the executive board meeting held in Columbus, Ohio, 30 November–1 December 1990 were approved as amended.

2. Johnston introduced Richard Adams and Steven Buccola of Oregon State University, coeditors of the *American Journal of Agricultural Economics* for the upcoming volumes 74–76.

3. Bruce Beattie, reporting on the progress of the invited paper sessions for the upcoming annual meeting, asked all board members who had not already done so to contact him by 1 February concerning the final roster of participants in the invited paper sessions for which they are responsible.

4. Richard Adams and Steven Buccola, coeditors for vol. 74–76 of the *AJAE* gave a progress report on the transfer of editorial functions. They reported that (*a*) Otto Doering, Purdue University, has agreed to serve as book review editor and has begun to make the transfer of this function from Ohio State to Purdue; (*b*) a board of associate editors has been identified and appointed; (*c*) an editorial assistant has been hired at Oregon State and is on the job; (*d*) a computer and printer has been purchased using AAEA funds; (*e*) the current list of reviewers is being updated; and, finally, that (*f*) manuscripts that are near acceptance are now being sent by current *AJAE* editor Peter Barry to the new coeditors as the November 1991 issue becomes filled.

Options available for a technical editor were discussed. Ideas advanced included locating the technical editor at Oregon State, at Iowa State, or at a third location.

MOTION: Katherine Reichelderfer moved that (*a*) the board ask the coeditors to identify the appropriate technical editor for placement in the business office, and (*b*) the board give the new editors the authority to identify and pursue other options if it is in the best interest of the *AJAE* to do so. Vernon Eidman seconded. Motion carried.

The coeditors advanced four proposals for board consideration:

(*a*) Honor the *AJAE's* 75th anniversary in 1993 by publishing a special issue that year.

(*b*) Sponsor a publishing and writing workshop in conjunction with the 1992 AAEA annual meeting.

The board requested that the editors further refine their first two proposals indicating the budget implications of each for presentation to the board in August.

(*c*) Establish an annual AAEA award for outstanding *Journal* referee.

This proposal was tabled until the coeditors have had more experience in working with reviewers and, hence, will be in a better position to evaluate the feasibility of an award of this kind.

(*d*) Develop an ad hoc committee to study the possibilities for electronic transmission of *AJAE* manuscript materials.

MOTION: Beattie moved that the evaluation of electronic transmission technology be pursued and that an ad hoc committee be appointed if the co-editors find that additional study of desk top publishing is warranted. Reichelderfer seconded. Motion carried.

5. Mike Ellerbrock, *AAEA Newsletter* editor, reported on his activities in connection with the *Newsletter*. He reported that he had conducted informal research as to whether our *Newsletter* is the primary vehicle for advertisements for agricultural economists, especially relative to the *CWAE Newsletter*. His results indicate the *AAEA Newsletter* is the primary outlet for academic positions. Ellerbrock also indicated that our fee structure for advertisements does not seem to discourage lengthy ads. The board agreed not to change the fee structure at this time.

6. Lyle Schertz reported to the board on the Kellogg project. He distributed a draft of the report of the evaluation committee and made the following points:

(*a*) This project has increased awareness among the press of the existence of an agricultural economics profession.

(*b*) The urban press is limited as to what it places on the airways, and this project continues to help make them aware of the association's existence and the range of materials relating to agricultural issues that is available to them.

(*c*) What does the future hold for the work of this project after the grant expires in 1992? Schertz suggested the possibility of obtaining industry sponsorship for activities of the type pursued by the current project. Schertz invited the board to respond with any reactions they may have concerning the conduct of the project.

7. Sandra Batie presented a proposed change to bylaws Article XV. *CHOICES*. Section 3. Editorial Advisory Board for *CHOICES*: strike the words "upon the recommendation of the Editor of *CHOICES*" so that the bylaws will read: Section 3. Editorial Advisory Board for *CHOICES*. Members of the Editorial Advisory Board shall be appointed by the President-Elect. This advisory board will have standing committee status, with members appointed for three-year staggered terms or other lengths of appointment as prescribed by the executive board of the association.

MOTION: Batie moved to approve the bylaw change. Brady Deaton seconded. Motion carried.

8. Schertz reported to the board concerning a joint project proposal for developing and distributing materials through the Joint Council on Economic Education. After a lengthy discussion the board agreed that the association ought to be moving in this direction but expressed reluctance to join hands with the JCEE at this time in an effort to obtain financing for such a project. Batie and Walter Armbruster are to think about what would be the best approach for the association in addressing the economic education area. They are to report at the August meeting. Johnston indicated his intention to attempt to arrange for Robert Highsmith to meet with the President's Council/

Board at Kansas State University in August for the purpose of clarifying what might be an appropriate arrangement for the AAEA to participate in the Council on Economic Education program.

The board adjourned for lunch to reconvene at 1:30 P.M.

9. Schertz and the board agreed that the former would proceed with plans for a sponsored essay contest and that Schertz would meet with the AAEA Foundation Governing Board at their next meeting to discuss arangements for foundation help in financing the essay contest. The contest is to be announced in the May 1991 issue of *CHOICES* magazine.

10. Vernon Eidman, reporting for the AAEA Foundation Governing Board, explained that a solicitation letter for contributions for the foundation had been sent to the entire membership of the association in early December. He reported the governing board expected that such a solicitation will become an annual event.

MOTION: Eidman moved that the board grant approval to the foundation to include the annual solicitation letter to the membership with the membership dues renewal form. Armbruster seconded. Motion carried.

11. Raymond Beneke brought the board up to date concerning the Workshop for the Enhancement of Professional Interaction among Economists in the Emerging Democracies. Beneke reported working with several foundations in the attempt to obtain financing for this project. Applications for an exchange between the countries have been prepared with Jan Hybel of Poland and Franc Fekete of Hungary. Warren E. Johnston and Bruce R. Beattie plan to participate in the exchange. Hybel and Fekete are anxious to meet with our organization and to visit the area. If requests for financial aid are not forthcoming, this project will be aborted on 1 April 1991.

MOTION: Armbruster moved the association cosponsor this project without assuming any financial obligations. Beattie seconded. Motion carried.

12. A lengthy discussion on a National Institutes of the Environment (NIE) initiative took place. Reichelderfer reported that the committee developed to study this proposal would like AAEA to (*a*) send a letter of endorsement/involvement; (*b*) advertise the NIE idea at the annual meeting; (*c*) make political contacts; (*d*) appoint a member to participate on working groups; and (*e*) provide data, information, and research results.

MOTION: Batie moved that the AAEA assist by identifying individuals interested in participation in NIE committee working groups and in providing data and information on agricultural economics and returns to resources invested in research. Deaton seconded. Motion carried. Reichelderfer volunteered to be the contact person.

The board meeting adjourned at 3:15 P.M. in order to tour the San Antonio Convention center and adjacent hotels as a potential annual meeting site. The board is to reconvene on Saturday morning at 9:00 A.M.

13. Charlene Carsrud, from the Business Office, reported on the 1990 annual meeting at Vancouver, B.C., Canada. Attendance figures were at a record high with a total of 2,302 registered, including spouses and children. Net profit was reported to be approximately $5,000.

14. Carsrud reported that Larry Libby had visited the proposed 1993 Orlando annual meeting site and found the hotel and area to be satisfactory, with self-contained meeting space and in-house as well as nearby eating facilities. The Clarion Hotel is ready to commit 650 sleeping rooms plus all meeting space, as well as an additional 200 sleeping rooms at a nearby Quality Inn. The board instructed the business office to negotiate with the hotels on signing a contract to hold the space for the 1993 annual meeting.

15. The board discussed the possibilities of holding the 1995 annual meeting in San Antonio. Because of scheduling conflicts for adequate meeting space at the convention center in 1995 and the fact the annual meeting will be held in San Diego in 1994, it was decided to negotiate for the dates available in 1996 and report to the board at the Manhattan meeting.

MOTION: Batie moved to have the business office continue to negotiate for space and better rates in San Antonio for the 1996 annual meeting. Eidman seconded. Motion carried.

Carsrud is to identify potential Midwest sites for the 1995 meeting and report to the board in August.

Carsrud announced a preliminary planning meeting was set for 6–7 March 1991 in Baltimore in preparation for the 1992 meeting. Involved in the meeting in addition to the business office staff will be President-Elect Beattie; Kenneth McConnell, AERE; Olan Forker, NAREA; Larry Davis, SWCS; Kathryn Lipton, ERS; and Earl Brown, University of Maryland.

16. Lona Christoffers, reporting for the business office, indicated that 61 participants are registered for the Conference on Economic Accounting for Commodity Costs and Returns being held in Kansas City, Missouri, 20–22 February 1991. This conference is being sponsored jointly by the Farm Foundation, the Economic Research Service, the Federal Extension Service, and AAEA. Mary Ahearn is in charge of the conference.

17. Johnston reported on recent activities of the ad hoc committee established to nominate a speaker for the Frederick V. Waugh Lecture at the Kansas State meeting. The call for nominees for a speaker has been published in the *AAEA Newsletter*. Johnston indicated that an appropriate bylaw will need to be drafted for board action at the August meeting in order to give the committee permanency. The board agreed that the committee should consist of four members: an ERS representative, a person selected for an initial two-year term, another for a normal three-year term, and the past president, who will act as chair.

18. The agreement between the National Agricultural Library and the AAEA, whereby the former would serve as the archives for the association, was discussed.

MOTION: Batie moved that the agreement be signed which would provide for materials to be shipped to the National Agricultural Library and that no investment in cataloging materials be made at this time. Beattie seconded. Motion carried.

19. A status report of the Postwar Literature Review, volume 4, was given by Beneke. He indicated that the Minnesota Press had given him a November 1991, publication date. Johnston reported that Carl Eicher was leading an ad hoc committee charged with identifying firms or foundations interested in funding distribution of the book in the underdeveloped world.

20. Christoffers reported on the status of membership renewals received by the business office to date. The figures show that the individual memberships are down by about 7% compared to the same time last year.

21. A letter concerning the International Crop Science Congress was discussed. After appropriate discussion the board agreed that Johnston, in responding, should indicate that AAEA agreed to observe as a cosponsor of the event without financial obligation, and that members of the association would be encouraged to provide input for the program. In addition the Congress would be invited to use the *AAEA Newsletter* as well as *CHOICES* magazine for publicizing the event.

22. Organizers of the extension luncheon inquired about the possibility of having a breakfast or a luncheon on a day other than Wednesday at the 1991 meeting because the normal rotation would schedule the extension luncheon on Wednesday in Manhattan. The board agreed that if facilities at Manhattan are sufficient to accommodate a luncheon on a day other than Wednesday, that the board would not object to such a modification with the understanding that the normal rotation of luncheons would continue in future years.

23. Johnston gave an update on the progress of the International Association of Agricultural Economists meeting tentatively scheduled to be held in the United States in 1994. The board agreed that Johnston should express an interest in the association being a cosponsor of this event without financial obligations and should offer any help that the association can provide.

24. The board discussed the matter of the upcoming preconference being planned by the Social Science Agricultural Agenda Project scheduled for Kansas City, Missouri, in August. Although this is an AAEA cosponsored event, the association will not share in the gains nor losses.

25. Board members reported on the survey each had conducted concerning the attitude of graduate students toward being integrated with the student section of the association. The consensus among graduate students polled was that they did not wish to be considered part of the undergraduate student section.

The board decided to have a reception at Kansas State for all undergraduate students, graduate students, and first-time attendees to the annual meeting. The purpose of this reception will be to provide newcomers an opportunity to meet the members of the board. The newcomers reception will be held immediately preceding the general reception. This event will be conducted on an experimental basis at the Manhattan meeting.

26. A request from the Student Section of the association for $4,600 to purchase basic equipment necessary to run the Academic Bowl at the annual meeting was discussed.

MOTION: Batie moved that because this proposal coincides with a current priority project of the AAEA Foundation, the request be submitted to the foundation for their consideration at their April meeting. Beattie seconded. Motion carried.

27. The board discussed the Council of Professional Associations on Federal Statistics.

MOTION: Johnston moved that we continue to support COPAFS and that we increase our support by 5% as requested, making the amount allocated to this group $7,277.00. Eidman seconded. Motion carried.

28. The board discussed the Consortium of Social Science Associations and the relationship of its activities to the AAEA.

MOTION: Batie moved that the association drop its membership in this organization. Reichelderfer seconded. Motion carried.

29. The board turned to a discussion of the Adaptive Planning Report and the actions, if any, the board might take to implement recommendations of the committee. The board discussed at length the implications of each of the recommendations. This session terminated with a series of motions as follows:

MOTION: Reichelderfer moved that the association experiment at the 1991 meeting in Manhattan and at the 1992 meeting in Baltimore with a format which provides for several open meetings initiated by individual or special interest groups interspersed with conventional sessions with the number limited by the availability of facilities. Beattie seconded. Motion carried.

MOTION: Beattie moved that the association accommodate, but not necessarily foster, the formation of interest groups. Batie seconded. Motion carried.

MOTION: Beattie moved that the board consider requests for dues check-off services by the association on a case-by-case basis. Activities and financing in each case would be the responsibility of the group. Eidman seconded. Motion carried.

MOTION: Deaton moved that requests by special interest groups for sevices from the business office, in addition to the dues check-off, be considered on a case-by-case basis. Libby seconded. Motion carried.

MOTION: Walter Armbruster moved that the board affirm that no change in the structure of the board nor in the election process is envisioned at this time. Eidman seconded. Motion carried.

MOTION: Batie moved that the recommendation of the Adaptive Planning Committee with respect to the appropriate structure of the professional staff services continue to be considered over the next several board meetings. Reichelderfer seconded. Motion carried.

Johnston is to respond to Otto Doering as to the results of this discussion.

30. The board took under consideration a policy for the treatment of monetary gains/losses associated with AAEA committee endeavors.

MOTION: Armbruster moved that henceforth net unused balances from funds raised for specific activities be made available for use by the committee or group on other board approved activities. No interest shall accrue to the funds held by committees or groups. Libby seconded. Motion carried.

31. Armbruster presented to the board the new format the Finance Committee had developed for use in presenting financial information. This format includes actual figures from the previous two years, proposed budgets for current and next year, and projections for the second- and third-year budgets. Enterprise budgets from a number of association categories will be presented in a consistent format.

A discussion as to the board allocation for *CHOICES* magazine took place.

MOTION: Armbruster moved to amend the 1991 budget to remove the *CHOICES* allocation and to modify the enterprise budget for *CHOICES* accordingly. Reichelderfer seconded. Motion carried.

32. MOTION: Armbruster moved that, henceforth, for budgeting purposes, the net operating income will not include the gain or loss from the sale of securities. A spending rule adopted in August 1990 provides that current operating expenses will be funded by current operating revenues plus not more that 3% of the average of the past three year-end equity balances excluding foundation and other restricted resources. Reichelderfer seconded. Motion carried.

33. Discussion of the Alexander von Humboldt Foundation Award for 1991 took place. It was suggested that Johnston ask for assistance in preparing a packet to nominate an association member for this award.

34. President Johnston raised the question of the necessity for hosting a reception at the ASSA meetings.

MOTION: Beattie moved that because of lack of attendance, the AAEA discontinue hosting a reception at the ASSA winter meeting. Batie seconded. Motion carried.

35. Johnston announced that the board meeting in Manhattan will start at 1:00 P.M., Friday, 2 August 1991. The meeting will continue Saturday and Sunday, as necessary.

The board meeting adjourned at 6:30 P.M.

Respectfully submitted,

Raymond R. Beneke
Secretary-Treasurer

Minutes of the AAEA Executive Board Meeting, Manhattan, Kansas, 2–4 August 1991

Present: Voting Members:
Armbruster, Batie, Beattie, Deaton, Eidman, Johnston, Libby, Reichelderfer

Members ex-officio:
Barry, Beneke, Schertz

Guests:
Adams, Buccola, Carsrud, Christoffers, Christy, Houck, van Ravenswaay, and others as reported in the minutes

The meeting of the Executive Board of the American Agricultural Economics Association was convened at 1:30 P.M. in the Council Chambers of the Kansas State Union on the campus of Kansas State University, Friday, 2 August 1991, by President Warren Johnston with announcements and a review of the proposed agenda. Johnston welcomed the newly elected board members present at the meeting. He commended the staff of Kansas State on the efficiency of the planning for this meeting. Johnston announced the winners of the Fellows election for 1991, the granting of ten International Travel Grants to the International Association of Agricultural Economists meeting in Tokyo, the apparent success of the Eastern European project, and the existence of the Peoples Republic of China Workshop. He also indicated that the deadline for the Invited Paper Sessions proposals, for the Waugh lecture nominees, for the Fellows nominees, and for suggestions for nominations for officers and directors had all been set for 15 October 1991.

1. The minutes of the executive board meeting held in San Antonio, Texas, 25–26 January 1991 were approved with the following correction: Item 32, page 9, was amended to read . . . A spending rule adopted in August 1990 provides that current expenses will be funded by current revenues including portfolio income, and not more than 3% of the average of the past three year-end equity balances, excluding foundation and other restricted resources.

2. Bruce Beattie, president-elect announced the 1991–92 committee assignments and the board representatives for each committee. Beattie indicated he was not reappointing the Information Retrieval Committee but assigning its functions to the Economic Statistics Committee.

MOTION: Beattie moved that the name of the Economic Statistics Committee be changed to Economic Statistics and Information Resources Committee to broaden the committee's charge. Larry Libby seconded. Motion carried.

Beattie explained that he had expanded the Industry Committee to more effectively accommodate agribusiness interests within the association.

3. It was noted that John Lee's office had prepared an outstanding nomination packet to support the association's nomination of Lyle Schertz, *CHOICES* editor, for the Alexander von Humboldt Award. The board then discussed the appointment of a committee to monitor the availability of extramural awards for which association members might be appropriate candidates.

4. Johnston summarized a letter from Harold Riley concerning the U.S. Council's proposal to the International Association of Agricultural Economists

inviting the group to meet in the U.S. in 1994. According to Riley, two sites, Washington, D.C., and Minneapolis, Minnesota, are being considered.

5. The International Crop Science Congress will hold the first International Crop Science Congress at Iowa State University, 14–22 July 1992. Beattie will appoint a liaison person to represent the AAEA at the congress.

6. Christoffers reported that over 100 persons had registered for the SSAAP preconference in Kansas City. Lester Manderscheid served as the AAEA representative to the meetings.

7. Beattie announced that the sessions for the 1992 ASSA meeting to be held in New Orleans had been finalized. The program will be published in the upcoming *AAEA Newsletter*. Beattie reminded the board that there would be no AAEA-sponsored reception at the 1992 meeting. The business office will prepare a simple program outlining the AAEA portion of the ASSA meeting for distribution in New Orleans.

8. Batie discussed her attendance at two National Academy of Science conferences in April of 1991, the Agricultural Sciences Intersociety meeting and the National Policy Conference on Undergraduate Education. The board agreed that the association needs to continue its involvement. Katherine Reichelderfer volunteered to be a representative of the AAEA to these meetings in 1992.

9. Reichelderfer presented a report on the National Institute for the Environment. She recommends that the AAEA remain nominally involved without investing a large amount of time and effort until more optimistic prospects warrant greater association investment in the NIE initiative.

10. Walter Armbruster reported on the Agribusiness Education Conference in May. This conference identified long-term activities with a potential to increase interaction between agribusiness and universities.

11. Brady Deaton reported on the national review of rural development centers and related projects. This was the first review held in twenty years. The review panel recommends that the USDA move these centers forward, increase their funding, and involve CSRS in their systematic review at five-year intervals.

12. Reichelderfer led a discussion related to the National Research Initiative. The board decided that Johnston and Beattie cosign a letter to Assistant Secretary Charles Hess urging that the initiatives be funded and that agricultural economists be appointed to all RFP committees and review panels.

13. Johnston reported on discussions with Vernon Schneider, secretary-treasurer of the International Agribusiness Management Association. Christoffers reported that Schneider recently visited the business office to investigate possible AAEA Business Office involvement in membership and financial services to the new association. Because no definite proposal was on hand from the IAMA, further discussion was postponed.

14. Christoffers reported that the proceedings issue from the 1988 modeling workshop has been accepted for publication by the Iowa State University Press and is scheduled to be available early next year. The proceedings from the "New Directions in Rural Data and Information Systems" has also been accepted for publication by ISU Press and that the publication process is now underway. According to the University of Minnesota Press, volume 4 of the Post-War Literature series is scheduled to be released late in 1991. ISU Press informed the business office that there are nine copies remaining of the book, *Agriculture and Rural Areas in the 21st Century*. Currently the press has no plans to print additional copies.

15. Johnston reported on a study of the use of CD-ROM for AAEA publications and electronic transmittal of membership lists. He concluded that CD-ROM technologies may have future promise, but currently the economic parameters of the process are not favorable for association investment in such ventures.

16. Johnston reported on correspondence between himself and Howard Silver on the nonrenewal of AAEA's affiliation with COSSA.

17. Charlene Carsrud, annual meeting coordinator, reported on the attendance at the Kansas State meeting. Figures show a preregistration total of 1,417 including spouse and guest registrants. Carsrud commended the leadership of on-site coordinator Ellen Stauffer for her organization and helpfulness. Carsrud also introduced Cindy Vogel, assistant meeting coordinator from the business office. Cindy has been employed in Ames as a work study student for the past three years and will be graduating in December.

18. Carsrud next reported that the Clarion Hotel, the Orlando, Florida, site for the 1993 annual meeting, is nearing completion with their first convention scheduled for September 1991. A letter from the president of the Caribbean Agro-Economic Society, Carlisle A. Pemberton, indicated a willingness on the part of the Caribbean Society to join with us for the 1993 meeting. Larry Libby is to work with President-Elect Jim Houck to develop interaction with the West Indies group for the 1993 meeting. The possibility of the Southern Association jointly sponsoring the Orlando meeting was discussed.

19. Johnston reported that the Mexican Association will be cosponsoring the AAEA 1994 annual meeting in San Diego, along with the Western Association.

20. Carsrud reported that a tentative confirmation has been reached with the various hotels in San Antonio to host the 1996 annual meeting. The board authorized Carsrud to proceed with negotiating a contract for the appropriate 1996 dates.

21. Carsrud reported on visits to Cincinnati, Ohio, and Indianapolis, Indiana, as possible Midwest sites for the 1995 annual meeting. A tentative hold is in place on hotel space at both locations. It was then decided to hold the fall board meeting 14–17 November 1991, in Cincinnati at the Westin Hotel, with an 8:00 A.M. start on 15 November. The winter board meeting will be held 10–12 January 1992, in Indi-

anapolis, with a 1:00 P.M. start on 10 January.

22. Raymond Beneke gave a brief overview of the International Outreach Program of the foundation, which is sponsoring the attendance of twelve agricultural economists from Eastern European countries to the 1991 annual meeting. Beneke stressed the desirability of continuing this type of project in the future and urged the board to interact with the individuals present.

MOTION: Armbruster moved that the board commend Ray Beneke on his excellent leadership of the Eastern European Outreach project. Kitty Reichelderfer seconded. Motion carried.

23. Beneke presented the secretary-treasurer's report indicating the association had ended 1990 with a net income of $14,310.00. He also indicated the need for placing greater emphasis on membership procurement in the future, and noted that membership for 1991 was down about 2%. Income and expense projections for 1992 and 1993 indicate that we should be operating in the black during these years.

24. Walter Armbruster, chair of the Finance Committee, reported that the format of the financial reports had been changed to make them more easily read and interpreted. He urged that efforts continue to improve the manner in which financial performance of the association is reported to the members. He suggested experimentation with greater emphasis on graphic presentations. Armbruster also suggested that quarterly financial statements be sent from the business office to the officers and Finance Committee with a cover letter indicating any concerns as to the actual expenses as compared to budget figures. The business office will begin to send such reports.

25. After discussion of the budget reports Armbruster moved,

MOTION: to increase the *AJAE* subscription price from the present $58.50 to $80.00. Eidman seconded and the motion carried. The discussion then turned to the possible adverse impact such an increase might have upon departmental reference room budgets. In the discussion it developed the departmental reference rooms already benefit from a generous special package rate whereby they receive the *AJAE*, CHOICES, *Newsletter*, *CWAE Newsletter*, *Handbook-Directory*, and the student *Journal* at a reduced rate. In an effort to affirm that it was the intent of the board that the increase should apply to departmental reference rooms as well as other subscribers, Reichelderfer moved,

MOTION: that the special package subscription rate to departmental reference rooms increase to $80.00. Beattie seconded. Motion carried.

Both the Armbruster motion to increase the subscription rate and the Reichelderfer motion to increase the special package subscription rate to departmental reference rooms were based on the presumption that $58.50 was the current subscription rate. Subsequently, with the revised subscription rate of $65.00 the motions were altered via mailed ballot on 15 August 1991, to increase the subscription rates to $90.00.

The business office is to investigate what other professional journals cost and bring this report before the board at a later date.

26. Wes Musser, president of the Northeast Association was present to report on the latter organization's cosponsorship of the 1992 meeting in Baltimore, along with the Soil and Water Conservation Society. The format of the program would include a merged set of selected paper sessions, two joint invited paper sessions, two joint organized symposia, a joint awards program, and separate business meetings.

27. Peter Barry, editor, gave a report on the fifth and final year of operations for the Illinois office of *AJAE*. New submissions continue to increase with the total number of new submissions over the five-year period at 348 per year. The average response time has been 71 days on the original submission, 31 days on the second submission, and 8 days on a third submission. Barry announced that Martha Luzader will be retiring 31 December 1991, after having served as technical editor for the *AJAE* for 15 years. Barry turned to the new coeditors for the remainder of the report.

28. Steven Buccola and Richard Adams stated that with considerable help from Peter Barry, transition of the *AJAE* editorial office from the University of Illinois to Oregon State University has gone smoothly. They reported 275 new submissions were logged between 1 February and 25 July, representing a 35% increase over the submission rate during the first half of 1990.

The coeditors brought to the attention of the board a change in editorial policy. They are currently returning papers on citation counts, departmental rankings, and related topics and are suggesting the authors submit the papers elsewhere, such as the *Journal of Economic Education*.

Plans are underway to publish a special issue of the *AJAE* in 1993 commemorating the 75th anniversary of the *AJAE*. The special issue will consist of essays in two broad topic areas: (*a*) the history, state, and future of agricultural economics research methodology (philosophy of our science); and (*b*) the condition and likely future of the agricultural economics profession. Three of the ten essay slots will be reserved for invited papers, with the remaining essay slots chosen competitively.

29. Bruce Beattie brought to the attention of the board the fact that he did not reappoint the Adaptive Planning Committee for 1991–92. It was his judgment that any follow-up needs of the board could be accomplished through specific requests for input and guidance from the Professional Activities Committee.

Beattie reported that progress has been made toward interest group ownership and control of component parts of the annual meeting program with the board's decision to add open/free sessions and the identification of sponsoring groups for invited paper sessions.

The Adaptive Planning Committee's issue of decoupling of association publication subscriptions from

membership fees needs additional thought.

Motion: Armbruster moved that given the uncertainty of budget impacts, the complexity of administering such a system, and the modest savings to individuals if the marginal costs were used to determine charges to members, the board decided not to take any action to alter the membership package at this time. This topic may need to be reexamined as association functions evolve. Batie seconded. Motion carried.

Beattie plans to write an article for the *Newsletter* outlining to the membership what the board has done in response to the APC's report.

30. Armbruster led a discussion concerning AAEA becoming more involved with economic education for youth. Kim Reda-Wilson was present as chair of the Economic Education Committee. She reported that the latter committee is looking for encouragement from AAEA to develop a working relationship with them to improve economic literature in grades K–12 and to put more agriculture into the curriculum.

Motion: Armbruster moved that the Economic Education Committee be reappointed and instructed to explore linkage of the AAEA with the Joint Council on Economic Education. Eidman seconded. Motion carried.

31. Johnston directed the board's attention to a letter from Robert G. Zimbelman, chair, Coalition on Funding Agricultural Research Missions (CO-FARM). After discussion Johnston will respond with a letter encouraging them to keep us informed of their progress.

32. Beattie announced the committee assignments for the coming year and thanked board members for their work with committees this past year. He urged board representatives to maintain close contact with the committees to enhance the effectiveness with which they serve their liaison function.

33. The report of the Extension Committee was discussed. The committee expressed a desire to host a premeeting conference in 1992 in Baltimore. The board will encourage the committee to submit a proposal to be discussed at the November board meeting. The committee will also explore the possibility of publishing a simple directory of AAEA members with extension interest by subject matter and geographical location. The board approved the use of up to $1,000 of Extension Committee funds for the publication of such a directory. Any expenditure in excess of $1,000 would require further approval by the board.

34. A report of the Resident Instruction Committee outlined a proposal for a workshop to be presented prior to the Southern Agricultural Economics Association meeting in Lexington, Kentucky, 31 January–1 February 1992. The proposal invites the AAEA board to cosponsor this workshop. The board decided to delay a decision pending further investigation into what role the committee is expecting the AAEA to play.

The Resident Instruction Committee also has plans for a teaching workshop to be held in conjunction with the 1992 meeting in Baltimore. The board instructed the committee to submit space requirements for such a workshop to Carsrud and to prepare a formal proposal and budget for the board's consideration at their November meeting.

35. President Johnston reported on the outcome of an executive session concerning *CHOICES* magazine and *CHOICES* personnel.

Because of potential conflict of interest problems, Assistant to the Editor, Marie E. Lee, d/b/a ps Express, is no longer able to be involved in the promotion of subscriptions for *CHOICES*. Lee will be responsible for writing and arranging for the writing of informational materials, acquiring mailing lists, managing the mailing process of informational materials, arranging for evaluation of informational materials, and preparing and managing the budget for these activities. The Memorandum of Understanding between ps Express and the association will be amended to reflect changes recently agreed to. Editor Schertz has agreed to deal with the promotion of group subscriptions to USDA agencies and university deans.

Motion: Armbruster moved that the Memorandum of Understanding between Lyle Schertz, d/b/a/ Economic Associates, and AAEA be amended to reflect additional compensation at the rate of $375 per day with a cap of $5,000 per year for the purpose of maintaining arrangements with USDA agencies and university deans in the promotion of group subscriptions and the fostering of up to five other organizations as group subscribers. Eidman seconded. Motion carried.

Beattie appointed a board committee consisting of Batie, Armbruster, and Houck to analyze the current arrangement with *CHOICES* and the support the association gives to it as a basis for board decisions about the future direction of the publication. The committee will work with the personnel of *CHOICES* and the business office to develop recommendations for consideration by the board at their November meeting.

36. The Professional Activities Committee (PAC) report, given by Paul Barkley, chair, indicated that the voluntary questionnaire distributed at Vancouver centering on perceptions of the annual meetings and how the meetings can be improved had been summarized and developed into a poster that is on display at the Kansas State meeting. Over the past year, the PAC has developed fliers to assist presenters as they prepare for the meetings. It was suggested that a flier be developed for invited papers, as was done for selected papers, posters, and organized symposia. Because of the success of the learning workshop in Vancouver, the PAC decided to develop a second workshop for the 1991 meeting. The PAC recommends that a committee be appointed to guide the planning of future workshops. After some discussion,

Motion: Reichelderfer moved that the board follow-up on the PAC recommendation that the president-elect establish a rotating ad hoc committee for the purpose of planning and implementing the learn-

ing workshop. The PAC is to generate the topic and identify the planning committee leaders. Armbruster seconded. Motion passed.

37. The board proceeded to work through the various categories of the budget and the activity budgets for 1992 and 1993.

MOTION: Armbruster moved that these figures be accepted as the preliminary budget figures and that the Finance Committee review the figures and present a final budget at the November meeting. Reichelderfer seconded. Motion carried.

38. Ray Beneke reported to the board his intention to step down from his position as secretary-treasurer at the end of the 1992 annual meeting in Baltimore. In following the recommendation of the Adaptive Planning Committee report, Beattie appointed a four-person committee consisting of Johnston, Reichelderfer, Eidman, and Richard Perrin to study the possibilities of a new organizational structure/business office arrangement and bring a recommendation to the board at the November meeting.

MOTION: Batie moved that if a subcommittee of the board needs to incur travel expenses for AAEA travel other than regularly scheduled board meeting travel, that the business office be contacted and the budget item amended. Reichelderfer seconded. Motion carried.

39. Jeff Dorfman and Mike Wetzstein, cochairs of the Selected Papers Committee, reported on the activities of the latter committee. Dorfman reported that 397 papers had been submitted and reviewed with 216, or 55%, being accepted. The use of key words to match papers with reviewers had worked well, and they recommend that the system be continued. The cochairs stressed the need to enforce eligibility rules in the submission of papers. They reported additionally that they had reduced the number of papers presented per session to allow more time for questions and answers. The cochairs suggested that in the future the deadline for paper submissions be 1 March or 7 March, using a postmarked deadline.

40. Mary Ahearn appeared before the board to report on the activities of the Economic Statistics Committee. Currently, the most critical activity of the committee is the establishment of a task force to develop standards for cost and return estimates. Vern Eidman has been asked to chair this task force. Ahearn asked that the board officially appoint appropriate members to the "Task Force on Standardization of Commodity Costs and Return Estimates." The board endorsed this activity without financial obligation. The board also decided to continue to allocate up to $1,000 to partially defray the costs for Leroy Hushak to attend the quarterly meetings of COPAFS in Washington, D.C. Hushak is chair of the COPAFS group for 1991. Ahearn also asked the board to consider assigning a liaison person to the Census of Agriculture Advisory Committee.

41. Wen Chern, chair of the Committee on Professional Relations between China and the United States, summarized a report of the activities of that committee including the upcoming 1992 Beijing Conference. The conference has been rescheduled for 20–25 August 1992. Chern requested that the board designate an AAEA representative to attend the conference. Brady Deaton will serve as the AAEA representative. The 1992 conference will be cosponsored by the AAEA without financial obligation. However, the AAEA Business Office will manage the funds for the conference, including the collection of registration fees. Chern will provide updated budget estimates for the 1992 Beijing conference for the AAEA November board meeting.

42. Richard Shumway, chair of the Awards Committee, presented revised nomination procedures for selected AAEA award categories. For the *Distinguished Undergraduate Teaching, Distinguished Extension Program, and Distinguished Policy Contribution* categories, the letter of nomination (maximum of 3 single-spaced pages) will be the centerpiece for evaluation. Each letter should contain a concise statement which summarizes the reasons the nomination is worthy of award. Shumway urged that the letter of nomination focus on hard evidence that the nominee meets the criteria by which entrants are judged. The committee is urging that supporting materials be limited to three items (videos, publications, etc). Such materials should represent the nominee's best examples of quality pertaining to the award category. The committee recommends that no other material be accepted.

MOTION: Beattie moved that the changes in nomination procedures suggested above be adopted. Batie seconded. Motion carried. For the *Publication of Enduring Quality* category, the committee on awards recommended that nominations should be accompanied by a short statement (maximum of 3 single-spaced pages) documenting the publication's contribution to the profession. The committee further urged that other than copies of the publication, no other material be accepted.

MOTION: Beattie moved that the changes in the nomination packet for the Publication of Enduring Quality award as described above be adopted. Eidman seconded. Motion carried. Because of the small number of nominees in several of the award categories, Shumway recommended that a minimum number of submissions be required before an award is considered for Extension, Undergraduate, Teaching, Policy, and Enduring Quality. If an insufficient number of nominations are received in a given year, the committee suggests the nomination materials automatically be retained and entered into the awards competition for that category the following year.

MOTION: Beattie moved that there be no minimum number of awards required to be given per year. Reichelderfer seconded. Motion carried.

Recommendations by Shumway regarding (*a*) the quality of Communication Award and (*b*) the Distinguished Policy Contribution Award, and (*c*) the membership requirements to be eligible to win an award will be refined for presentation at the November meeting.

43. John E. Lee, Jr., administrator of ERS USDA

spoke briefly to the board and commented favorably on the SSAAP preconference in Kansas City held prior to the Manhattan meeting.

44. Batie recommended the following change be made in the bylaws: Article X, Section 5, Travel Expenses of the Executive Board. Change by removing the words "October/November executive board meeting" and replace them with the following italicized words: *other than annual summer meeting or Allied Social Science Association* meeting, members of the executive board will also be reimbursed for lodging costs."

MOTION: Batie moved that the bylaw change be adopted as discussed. Armbruster seconded. Motion carried.

After some brief comments by President Johnston and outgoing board members Batie and Armbruster, the meeting was adjourned.

Respectfully submitted,

Raymond R. Beneke
Secretary-Treasurer

Minutes of the Annual Business Meeting, Kansas State University, Manhattan, Kansas, 6 August 1991

President Warren E. Johnston called the meeting to order at 8:00 A.M. in McCain Auditorium on the campus of Kansas State University. The minutes of the 1990 annual business meeting, Vancouver, British Columbia, were approved as printed in the December 1990 *AJAE*.

1. Johnston introduced the newly elected officers of the association: President-elect James P. Houck, Director Ralph Christy, and Director Eileen O. van Ravenswaay.

2. Johnston reported on his successful term of office as president of the association. (The complete report of the president appears elsewhere in this issue.)

3. Raymond R. Beneke gave the report of the secretary-treasurer. (The complete report of the secretary-treasurer appears elsewhere in this issue.)

4. Walter Armbruster, chair of the Finance Committee reported that the budget format has been revised to make as clear as possible the income and expenses for each of the major AAEA activities. Also included are budget projections for the next two years to help identify potential problems before they reach a critical stage. The 1991, 1992, and 1993 budgets were distributed to the members in attendance, as well as 31 December 1989 and 1990 balance sheets. (A complete Finance Committee report and financial statements appear elsewhere in this issue.)

5. Speaking on behalf of the AAEA Foundation Governing Board, Kenneth R. Farrell, president, reported on the foundation's sixth year of continued growth in assets and program activities. A highlight of the 1991 meeting was an International Outreach Project whereby, in collaboration with agribusiness, other organizations and individuals, travel assistance was provided enabling twelve agricultural economists from Eastern Europe and the USSR to attend the AAEA meeting in Manhattan. (The AAEA Foundation report appears elsewhere in this issue.)

6. Peter Barry, editor of the *AJAE*, reported on the progress of volume 72 and other activities of the *AJAE* editor's office. He pointed out that new submissions of manuscripts continue to increase steadily. Barry announced that Martha Luzader will be retiring after fifteen years of service as technical editor of the *AJAE*. (A complete report of the editor appears elsewhere in this issue.)

Johnston presented a plaque to Peter Barry thanking him for his five years of outstanding service as the editor of the *AJAE*. Johnston also arranged to have presented to Martha Luzader a certificate for her fifteen years of high-quality work as technical editor.

Steve Buccola and Rich Adams, coeditors of the *AJAE* for volumes 74–76 each reported on the transition process and the progress being made to continue the smooth operation of the *AJAE*.

7. Lyle Schertz, editor of *CHOICES* magazine, announced progress on a special manuscript competition. The September 1992 issue of *CHOICES* will focus on prospective food, farm, and resource issues. Members of the association and others will be invited to submit articles on a competitive basis. Schertz also reported that the joint Kellogg project between AAEA and the American Agricultural Editors' Association is entering its final year. (A complete report of the editor appears elsewhere in this issue.)

8. Sandra Batie read changes made by the executive board in the AAEA bylaws. Those changes include:

A. ARTICLE XII, STANDING COMMITTEES.

Change the name of Economic Statistics Committee to Economic Statistics and Information Resources Committee.

B. ARTICLE V, AWARDS PROGRAM.

Change the article so that there will be no *minimum* number of awards required to be given per year.

C. ARTICLE X, SECTION 5, TRAVEL EXPENSES OF THE EXECUTIVE BOARD

Change by removing the words "October/November executive board meeting" and replace them with the following italicized words: For the executive board meetings, *other than annual summer meeting or Allied Social Science Association* meeting, members of the executive board will also be reimbursed for lodging costs.

9. James P. Houck, president-elect, read the following resolution:

Resolution

Because the officers, members, families, and guests of the American Agricultural Economics Association sincerely wish to recognize the efforts and warm hospitality of our hosts for the 31st annual meeting held

at Kansas State University on 4 August to 7 August 1991:

We resolve that the American Agricultural Economics Association expresses its gratitude for this effort and hospitality to Marc Johnson, Ellen Stauffer, and all other members and affiliates of the Department of Agricultural Economics, Kansas State University, for arranging and organizing the events and activities of this meeting.

We resolve that the association express its appreciation to President Jon Wefald and the administration of Kansas State University for making these fine university facilities available for this meeting.

We resolve that the American Agricultural Economics Association expresses its sincere appreciation to Charlene Carsrud, annual meeting coordinator, Cindy Vogel, assistant annual meeting coordinator, Lona Christoffers, business office coordinator, Jaye Stefani, employment center coordinator, and all others in the AAEA business office for their diligent efforts in coordinating and facilitating this meeting.

MOTION: Houck moved this resolution be adopted. The motion was seconded and approved.

10. Johnston recognized the retiring board members, Sandra Batie, Walter Armbruster, and Gene Futrell for their service to the board and the association. Plaques were presented to Batie and Armbruster and to Dennis Starleaf on behalf of the family of Gene Futrell.

11. Johnston expressed his appreciation to the membership, the board, and the business office for all their support during his term of office and to Marc Johnson and the staff at Kansas State University for the superb hospitality extended the officers and members of the association. He then passed the gavel on to President-Elect Bruce R. Beattie.

12. President Beattie reminded the group of the ASSA meeting to be held in New Orleans, Louisiana, on 2–5 January 1992, and issued an invitation to all present to attend the 1992 annual meeting at the inner harbor area of Baltimore, Maryland.

The business meeting adjourned.

Respectfully submitted,

Raymond R. Beneke
Secretary-Treasurer

Index to Volume 73

Subjects

Classification System

Chang, Hui-Shung, and Henry W. Kinnucan, "Advertising, Information, and Product Quality: The Case of Butter." 1195–1203.

Chavas, Jean-Paul, and Matthew T. Holt, "On Nonlinear Dynamics: The Case of the Pork Cycle." 819–28.

de Janvry, Alain, and Elisabeth Sadoulet, "The Impact of Increased Food Production on Less Developed Country Food Imports: A Reply." 506.

Devaney, Barbara, and Robert Moffitt, "Dietary Effects of the Food Stamp Program." 202–11.

Dorfman, Jeffrey H., and Arthur Havenner, "State-Space Modeling of Cyclical Supply, Seasonal Demand, and Agricultural Inventories." 829–40.

Dorfman, Jeffrey H., and Christopher S. McIntosh, "Results of a Price Forecasting Competition: Reply." 1277–78.

Gormely, Patrick J., "The Impact of Increased LDC Food Production on LDC Food Imports: Comment." 503–5.

Gould, Brian W., Thomas L. Cox, and Federico Perali, "Demand for Food Fats and Oils: The Role of Demographic Variables and Government Donations." 212–21.

Green, Richard, and Julian M. Alston, "Elasticities in AIDS Models: A Clarification and Extension." 874–75.

Holloway, Garth J., "The Farm-Retail Price Spread in an Imperfectly Competitive Food Industry." 979–89.

Horton, Susan, and Cathy Campbell, "Wife's Employment, Food Expenditures; and Apparent Nutrient Intake: Evidence From Canada." 784–94.

Nelson, Julie A., "Quality Variation and Quantity Aggregation in Consumer Demand for Food." 1204–12.

Quiggin, John, "Supply Response Under Proportional Profits Taxation." 36–39.

Sexton, Richard J., Catherine L. Kling, and Hoy F. Carman, "Market Integration, Efficiency of Arbitrage, and Imperfect Competition: Methodology and Application to U.S. Celery." 568–80.

Stoddart, Harry R., "The North American Hog and Pork Industry: Implications of a Countervailing Duty on Pork." 1562–69.

Tegene, Abebayehu, "Results of a Price Forecasting Competition: Comment." 1274–76.

Willett, Lois Schertz, and Ben C. French, "An Econometric Model of the U.S. Beekeeping Industry." 40–54.

Economic Growth and Development; Planning Models, Fluctuations; Technological Change; Aggregate Production Capacity; Regional and Community; Migration

Bernat, G. Andrew, Jr., and Thomas G. Johnson, "Distributional Effects of Household Linkages." 326–33.

Dagher, Magid A., Ralph D. Christy, and Patricia E. McLean-Meyinsse, "Limited Resource Farmers and the Marketing System." 1485–89.

Davis, Leroy, "Limited Resource Farmers: The Impact of Farm Policy." 1476–79.

Deller, Steven C., and Carl H. Nelson, "Measuring the Economic Efficiency of Producing Rural Road Services." 194–201.

Due, Jean M., and Christina H. Gladwin, "Impacts of Structural Adjustment Programs on African Women Farmers and Female-Headed Households." 1431–39.

Fan, Shenggen, "Effects of Technological Change and Institutional Reform on Production Growth in Chinese Agriculture." 266–75.

Gebremedhin, Tesfa G., "Limited Resource Farms and the Marketing System: Discussion." 1492–93.

Haggblade, Steven, Jeffrey Hammer, and Peter Hazell, "Modeling Agricultural Growth Multipliers." 361–74.

Hamilton, Joel R., Norman K. Whittlesey, M. Henry Robison, and John Ellis, "Economic Impacts, Value Added, and Benefits in Regional Project Analysis." 334–44.

Jones, Dewitt, "Agricultural Economics and Limited Resource Farmers Production Decisions: Discussion." 1494–95.

Knudson, Mary K., "Incorporating Technological Change in Diffusion Models." 724–33.

Larson, Bruce A., and Mary K. Knudson, "Public Regulation of Agricultural Biotechnology Field Tests: Economic Implications of Alternative Approaches." 1074–82.

Leathers, Howard D., and Melinda Smale, "A Bayesian Approach to Explaining Sequential Adoption of Components of a Technological Package." 734–42.

Lele, Uma, "The Gendered Impacts of Structural Adjustment Programs in Africa: Discussion." 1452–55.

Lemieux, Catharine M., and Michael K. Wohlgenant, "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin: Reply." 1284–87.

Lin, Justin Yifu, "Education and Innovation Adoption in Agriculture: Evidence from Hybrid Rice in China." 713–23.

Luh, Yir-Hueih, and Spiro E. Stefanou, "Productivity Growth in U.S. Agriculture Under Dynamic Adjustment." 1116–25.

Mehra, Rekha, "Can Structural Adjustment Work for Women Farmers?" 1440–47.

McMillan, Melville L., and Joe Amoako-Tuffour, "Demands for Local Public Sector Outputs in Rural and Urban Municipalities." 313–25.

Meltzer, Martin I., "*Ex Ante* Evaluation of the Economic Impact of Agricultural Biotechnology: The Case of Porcine Somatotropin: Comment." 1279–83.

Nelson, Mack C., Nathaniel B. Brown, Jr., and Letitia F. Toomer, "Limited Resource Farmers' Productivity: Some Evidence from Georgia." 1480–84.

Sahn, David, and Lawrence Haddad, "The Gendered Impacts of Structural Adjustment Programs in Africa: Discussion." 1448–51.

International Economics; Trade; Integration; Business; Aid

Marketing; Agribusiness; Cooperatives; Transportation; Industrial Organization; Vertical Coordination

National Resources; Energy; Conservation; Environment; Wastes; Land Use and Tenure; Recreation; Water; Fisheries

Hellerstein, Daniel M., "Using Count Data Models in Travel Cost Analysis with Aggregate Data." 860–66.
Hoag, Dana L., and Herb A. Holloway, "Farm Production Decisions Under Cross- and Conservation Compliance." 184–93.
Hoehn, John P., "Valuing the Multidimensional Impacts of Environmental Policy: Theory and Methods." 289–99.
Johnson, Scott L., Richard M. Adams, and Gregory M. Perry, "Assessing the On-Farm Costs of Reducing Groundwater Pollution." 1063–73.
Önal, Hayri, Bruce A. McCarl, Wade L. Griffin, Gary Matlock, and Jerry Clark, "A Bioeconomic Analysis of the Texas Shrimp Fishery and Its Optimal Management." 1161–70.
Roberts, Tanya, and David Smallwood, "Data Needs to Address Economic Issues in Food Safety." 933–42.
Torell, L. Allen, Kenneth S. Lyon, and E. Bruce Godfrey, "Long-run Versus Short-run Planning Horizons and the Rangeland Stocking Rate Decision." 795–807.
Ready, Richard C. and Richard C. Bishop, "Endangered Species and the Safe Minimum Standard." 309–12.

Production Economics and Management; Risk and Uncertainty

Bravo-Ureta, Boris E., and Laszlo Rieger, "Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassical Duality." 421–28.
Collins, Alan, Wesley N. Musser, and Robert Mason, "Prospect Theory and Risk Preferences of Oregon Seed Producers." 429–35.
Dawson, Philip J., John Lingard, and Christopher H. Woodford, "A Generalized Measure of Farm-Specific Technical Efficiency." 1098–1104.
Devadoss, S., and E. Kwan Choi, "Factor Price Stabilization and the Competitive Firms." 749–56.
Driscoll, Paul J., and Richard Boisvert, "Dual Second- and Third-Order Translog Models of Production." 1146–60.
Fackler, Paul L., "Modeling Interdependence: An Approach to Simulation and Elicitation." 1091–97.
Finkelshtain, Israel, and James A. Chalfant, "Marketed Surplus Under Risk: Do Peasants Agree with Sandmo?" 557–67.
Foster, William E., and Gordon Rausser, "Farmer Behavior Under Risk of Failure." 276–88.
Hanson, Steven D., and George W. Ladd, "Robustness of the Mean-Variance Model with Truncated Probability Distributions." 436–45.
Harl, Neil E., "Financing Agriculture Under Changing Environmental Regulation: Discussion." 1407–9.
Heisey, Paul W., and John P. Brennan, "An Analytical Model of Farmers' Demand for Replacement Seed." 1044–52.
Hertzler, Greg, "Dynamic Decisions Under Risk: Applications of Ito Stochastic Control in Agriculture." 1126–37.
Hiebert, L. Dean, "*Ex Post* Flexibility and Choice of Capacity for Loss Reduction." 490–95.
Huffaker, Ray G., and James E. Wilen, "Animal Stocking Under Conditions of Declining Forage Nutrients." 1213–23.
Knapp, Keith C., and Kazim Konyar, "Perennial Crop Supply Response: A Kalman Filter Approach." 841–49.
Leathers, Howard D., "Allocable Fixed Inputs as a Cause of Joint Production: A Cost Function Approach." 1083–90.
Mazzocco, Michael A., "Environmental Regulations and Agricultural Lending." 1394–98.
Meyer, Jack, and Lindon J. Robison, "The Aggregate Effects of Risk in the Agricultural Sector." 18–24.
Moschini, Giancarlo, "A Model of Production with Supply Management for the Canadian Agricultural Sector: Reply." 871–73.
Moss, Charles B., "Financing Agriculture Under Changing Environmental Regulation: Discussion." 1405–6.
Nelson, Carl H., "A Model of Production with Supply Management for the Canadian Agricultural Sector: Comment." 868–70.
Olexa, Michael T., "Contaminated Collateral and Lender Liability and the New Age Banker." 1388–93.
Pope, Rulon D., and Richard E. Just, "On Testing the Structure of Risk Preferences in Agricultural Supply Analysis." 743–48.
Turvey, Calum G., "Environmental Quality Constraints and Farm-Level Decision Making." 1399–1404.
Weersink, Alfons, and Loren W. Tauer, "Causality between Dairy Farm Size and Productivity." 1138–45.
Young, Douglas L., David J. Walker, and Paul L. Kanjo, "Cost Effectiveness and Equity Aspects of Soil Conservation Programs in a Highly Erodible Region." 1053–62.

Public Issues and Policy; Agricultural Regulations; Taxation; Inflation, Welfare Programs; Poverty; Regional and Community Development; Education; Health

Abler, David G., "Campaign Contributions and House Voting on Sugar and Dairy Legislation." 11–17.
Antle, John M., "Farm Policy Reform and the Environment." 917–21.
Anderson, Margot, and Bruce A. Larson, "International Technology Transfer: Private Channels and Public Welfare." 892–97.
Boyd, Roy, and David H. Newman, "Tax Reform and Land-Using Sectors in the U.S. Economy: A General Equilibrium Analysis." 398–409.
Burrell, Alison, "The Efficiency of Alternative Pol-

Research Methodology: Modeling; Econometrics; Mathematical Programming; Agricultural Data

Authors

Reviews

P8898

The

Australian Journal of Agricultural Economics

VOL. 35 | APRIL 1991 | NO. 1

Articles

Published by
THE AUSTRALIAN AGRICULTURAL ECONOMICS SOCIETY
ISSN 0817–8763

Editors of the *Journal of Farm Economics* (vols. 1–49) and

American Journal of Agricultural Economics (vols. 50–76)

L. A. Moorhouse	Office of Farm Management, USDA	Vols. 1–3	1919–21
O. C. Stine	Bureau of Agricultural Economics, USDA	4–6	1922–24
E. G. Nourse	Institute of Economics Brookings Institution	7–8	1925–26
H. R. Tolley	Bureau of Agricultural Economics, USDA	9–11	1927–29
H. E. Erdman	University of California-Berkeley	12–14	1930–32
O. B. Jesness	University of Minnesota	15–17	1933–35
H. C. M. Case	University of Illinois	18–19	1936–37
T. W. Schultz	Iowa State University	20–23	1938–41
H. B. Price	University of Kentucky	24–25	1942–43
Warren C. Waite	University of Minnesota	26–30	1944–48
Walter W. Wilcox	Library of Congress	31–33	1949–51
Lawrence W. Witt	Michigan State University	34–36	1952–54
Harold G. Halcrow	University of Connecticut	37–39	1955–57
Robert L. Clodius	University of Wisconsin	40–41	1958–59
Herman M. Southworth	Pennsylvania State University	42–44	1960–62
James Nielson	Michigan State University	45–47	1963–65
Earl R. Swanson	University of Illinois	48–50	1966–68
Varden Fuller	University of California Berkeley (1969) Davis (1970–71)	51–53	1969–71
Leo Polopolus	University of Florida	54–55	1972–73
Max R. Langham and Leo Polopolus, coeditors	University of Florida	55–56	1973–74
William G. Tomek	Cornell University	57–59	1975–77
V. James Rhodes	University of Missouri	60–62	1978–80
James P. Houck	University of Minnesota	63–65	1981–83
Richard E. Just and Gordon C. Rausser	University of California, Berkeley	66–68	1984–86
Peter J. Barry	University of Illinois	69–73	1987–91
Steven T. Buccola and Richard M. Adams coeditors	Oregon University	74–76	1992–94

American Agricultural Economics Association

President/Bruce R. Beattie, University of Arizona
President-Elect/James P. Houck, University of Minnesota
Secretary-Treasurer/Raymond R. Beneke, Iowa State University
Past-President/Warren E. Johnston, University of California, Davis

Directors

Ralph Christy, Cornell University
Brady J. Deaton, University of Missouri
Vernon R. Eidman, University of Minnesota
Lawrence W. Libby, University of Florida
Katherine H. Reichelderfer, USDA/ERS
Eileen van Ravenswaay, Michigan State University

Objective

The American Agricultural Economics Association (AAEA) seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy.

AAEA

—publishes the *American Journal of Agricultural Economics*, the *AAEA Newsletter*, *Choices*—The Magazine of Food, Farm, and Resource Issues, and, periodically, a *Handbook-Directory* of AAEA members;
—plans and conducts an annual meeting of the membership;
—sponsors awards for Distinguished Undergraduate Teaching, Distinguished Extension Programs, Distinguished Policy Contribution, Publication of Enduring Quality, Outstanding Journal Article, Quality of Communication, Quality of Research Discovery, Outstanding Master's Thesis, and Outstanding Ph.D. Dissertation;
—recognizes prominent agricultural economists as Fellows;
—operates the AAEA Employment Service for agricultural economists.

Membership and Subscriptions

AAEA is a professional society for agricultural economists and others who are interested in agricultural economics. A nonprofit organization, AAEA is committed to furthering knowledge about the economics of agriculture, rural communities, and natural resources.

Membership in the AAEA will bring you *Choices*, the *AJAE*, the *AAEA Newsletter*, and other occasional AAEA publications, permit you to use the AAEA Employment Service, and allows you to attend the annual meetings.

Calendar year dues are: $60, regular members; $30, senior (retired and 65) and junior (student) members; $90, family members; $170, industry members. Lifetime membership is available for members who are at least 55.

Subscription prices: *American Journal of Agricultural Economics*—$65 per year ($73 overseas); single copies, $14.50. *Choices*—The Magazine of Food, Farm, and Resource Issues—$32.50 per year ($52.50 overseas); single copies, $10. *AAEA Newsletter*—$12 per year ($17 overseas).

For further information about the American Agricultural Economics Association, contact the AAEA Business Office, 80 Heady Hall, Iowa State University, Ames, Iowa 50011-1070 (515-294-8700).